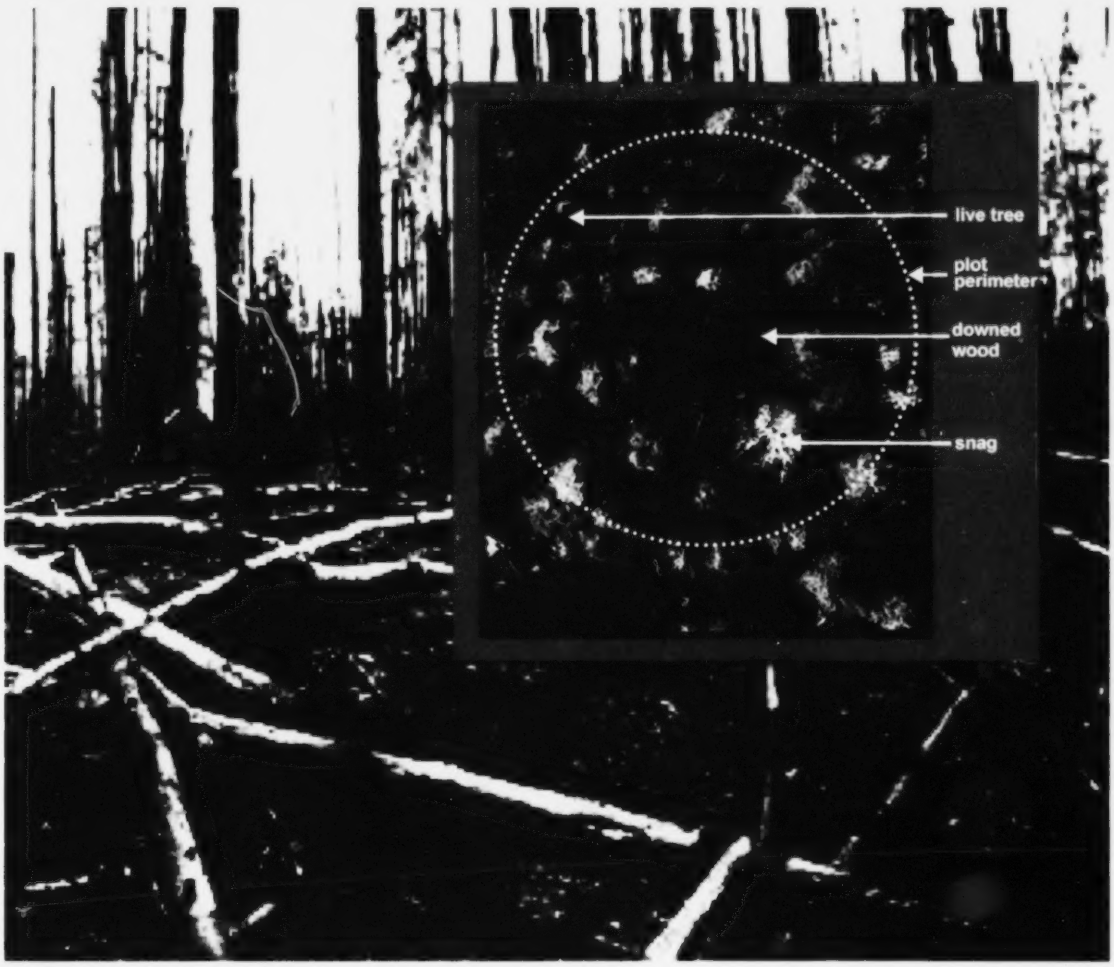
Forest Research Information Paper **169**

Sampling methodology for studying boreal post-fire residual stand structure with high resolution aerial photography and field plots



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Sampling methodology for studying boreal post-fire residual stand structure with high resolution aerial photography and field plots

by

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2007

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Abstract

This report documents the use of high resolution aerial photography as an alternative to traditional field sampling methods for assessing post-fire residual structure. High resolution photography (HRP), also termed large scale photography (LSP), refers to aerial photographs interpreted at scales of 1:2,500 or larger. Eleven fires were selected for sampling across boreal Ontario in 2005. Within fires, HRP was used to sample residual structure, i.e., trees, snags, and downed wood, in point samples of 0.05 ha circular plots within one to four months post-fire ignition. Fifty field plots were established in four of the sample fires for error assessment of photo-interpretation and to allow short-term monitoring of changes in post-fire residual structure. Methods used to select fires, capture and interpret sample photographs, and establish and assess field sample plots are described. Approximate costs of collecting comparable residual structure data were $130 per plot for HRP vs. $1,012 per plot for field sampling. When error assessment costs were included in HRP estimates, per plot costs rose to $217. Half the cost of HRP sampling was for photo capture, including helicopter ferry time. Nearly one third of the field sampling cost was for labour, while another third were operational costs.

Resumé

Le présent rapport traite de l'utilisation de la photographie aérienne haute définition comme solution de rechange aux méthodes d'échantillonnage conventionnelles sur le terrain, pour étudier la structure des peuplements résiduels après un incendie. La photographie haute résolution, aussi dite photographie à grande échelle, se rapporte aux photos aériennes interprétées à une échelle d'au moins 1:2 500. Onze peuplements incendiés ont été échantillonnés en 2005, à divers endroits de l'Ontario boréal. La photographie haute définition a été utilisée pour déterminer la structure des arbres, des chicots et du bois gisant dans des parcelles circulaires de 0,05 ha, entre un et quatre mois après le début des incendies. Cinquante parcelles ont été établies dans quatre des peuplements sélectionnés pour noter le nombre des erreurs associées à l'interprétation par des photos, et pour pouvoir surveiller les changements que subissent les structures résiduelles pendant une courte période après un incendie. Le rapport décrit les méthodes qui ont été employées pour sélectionner les peuplements incendiés, prendre et interpréter les photos, et établir et évaluer les parcelles. Le coût approximatif pour recueillir des données comparables a été de 130 $ par parcelle pour la photographie haute définition et de 1 012 $ par parcelle pour l'échantillonnage sur le terrain. Lorsque le coût lié aux erreurs est incorporé dans le coût approximatif, le coût par parcelle a atteint 217 $ pour la photographie haute définition. La prise des photos (dont le temps de vol en hélicoptère) représente la moitié du coût de l'échantillonnage par photographie haute définition. La main-d'œuvre représente près du tiers du coût de l'échantillonnage sur le terrain, et les frais de fonctionnement représentent un tiers du coût.

Acknowledgements

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Introduction

Post-fire forest structure, also referred to as *residuals*, includes standing live and dead trees (snags) and downed wood. Measurement of forest structure following fire disturbances provides baseline data for wildlife studies (Apfelbaum and Haney 1981, Schulte and Niemi 1998, Hobson and Schieck 1999), for comparison against forest harvest disturbances (Lee and Crites 1999, Haeussler and Bergeron 2004), and is important to understanding fire behaviour (Lutz 1956, Wang 2002), forest succession (e.g., Hansen 1983, Graf et al. 2000, Awada et al. 2004, Harper et al. 2005) and carbon input, storage and flux (Nalder and Wein 1999, Bond-Lamberty et al. 2003, Manies et al. 2005). A review of the literature showed that various field-based methods have been used to sample this structure in North American boreal and near-boreal (i.e., Great Lakes-St. Lawrence after Rowe 1972) forests (Table 1). Early studies relied mainly on observation but, more recently, the most commonly used approaches are plot-based. Interestingly, the studies found in the literature relied almost exclusively on field sampling approaches to measure residuals.

Traditional field sampling is costly due to the time and personnel required (Rhody 1977, Hall 1984, Spencer and Hall 1988, Hall et al. 2001), leading to exploration and assessment of other approaches. Another sampling method that could be used to sample residual structure immediately after fires is aerial photography. High resolution photography (HRP) refers to aerial photographs interpreted at scales of 1:2,500 or larger. The HRP approach, also referred to in the literature as large-scale photography or LSP, has been used for many forest management related applications, including measuring forest stand structure (Avery 1958, Avery 1959, Chapman and Cole 2006), surveying forest regeneration (Kippen and Sayn-Wittgenstein 1964, Hall and Aldred 1992), inventorying forest fuels (Muraro 1970), classifying habitat (Befort 1986), and estimating tree mortality (Croft et al. 1982). I found only two instances of its use to estimate post-fire densities of residual live trees and snags (DeLong and Tanner 1996, 40-60 years post-fire; McCleary 2005, 1 year post-fire) and downed wood (McCleary 2005), both in western North American coniferous forests.

The HRP approach provides many advantages over traditional field sampling. For example, many plots can be sampled across multiple areas in a short period of time with no concerns about ground access to the area. Photos also provide a permanent record of sample plots and can be interpreted at any time of the year (Muraro 1970, Hall 1984), reinterpreted if necessary, or used to support other objectives in subsequent analyses. On the other hand, some variables that can be measured in the field cannot be interpreted from photographs. And while some field sampling is still required to assess photo-interpretation error rates, this can be minimal, potentially reducing per plot sampling costs.

The intent of this report is to document the use of high resolution aerial photography as an alternative to traditional field sampling methods for assessing post-fire residuals. Specifically I describe the use of helicopter-acquired, high resolution aerial photography (HRP) to sample post-fire stand structure (trees, snags, and downed wood) during a study of post-fire residuals in recent unsuppressed fires across Ontario's boreal forest (see Perera and Buse 2006 for details about broader study goals). In addition, I describe the sampling methods used for assessing post-fire residual structure in the field (for error analysis of photo-interpreted data and to follow short-term (3 year) post-fire structural changes in the above study). Subsequently, I compare the two sampling methods in terms of feasibility and cost.

Although this report focuses specifically on assessing post-fire structure, the sampling methods described here are broadly applicable to other types of stand structure studies.

Table 1. *Sampling techniques used in publications reporting post-fire stand structure within 20 years of a fire occurring in North American boreal and near-boreal forest. Number of non-duplicating publications indicated in parentheses.*

Sampling technique	Structure sampled Trees (n = 14)	Snags (n = 41)	Downed wood (n = 21)
Aerial photography (n = 0)	None	None	None
Observation (n = 7)	Apfelbaum and Haney 1986 Lutz 1956 Methven et al. 1975 Nordin and Grigal 1976	Apfelbaum and Haney 1986 Lutz 1956 Methven et al. 1975 Nalder and Wein 1999 Nordin and Grigal 1976 Scotter 1972 van Wagner 1973	Methven et al. 1975
Plot (n = 29)	Apfelbaum and Haney 1981 Haeussler and Bergeron 2004 Harper et al. 2004 Hobson and Schieck 1999 Kemball 2002 Kurulok 2004 le Goff and Sirois 2004 Schulte and Niemi 1998 Stuart-Smith et al. 2002 Viereck and Dyrness 1979	Apfelbaum and Haney 1981 Awada et al. 2004 Bond-Lamberty et al. 2003 Drapeau et al. 2002 Haeussler and Bergeron 2004 Hansen 1983 Harper et al. 2004 Hely et al. 2003 Hobson and Schieck 1999 Imbeau et al. 1999 Kemball 2002 Kurulok 2004 Larivee 2003 Miyanishi and Johnson 2002 Nappi et al. 2003 Ohmann and Grigal 1979 Pedlar et al. 2002 Saint-Germain et al. 2004 Sander 2003 Schulte and Niemi 1998 Simon et al. 2002 Stambaugh 2003 Stepnisky 2003 Stuart-Smith et al. 2002 Viereck and Dyrness 1979 Wang 2002	Bond-Lamberty et al. 2003 Capar 2004 Haeussler and Bergeron 2004 Hansen 1983 Harper et al. 2004, 2005 Hobson and Schieck 1999 Kemball 2002 Larivee 2003 Pedlar et al. 2002 Saint-Germain et al. 2004 Sander 2003 Schulte and Niemi 1998
Plotless (n = 3)	None	Ferguson and Elkie 2003 Lavoie 2004 le Goff and Sirois 2004	None
Transect (n = 7)	None	Beverly and Martell 2003 Graf et al. 2000 Manies et al. 2005	Graf et al. 2000 Kurulok 2004 Lavoie 2004 Manies et al. 2005 Morissette et al. 2002 Schaefer and Pruitt 1991
Not specified (n = 1)	None	Lee and Crites 1999	Lee and Crites 1999

Background

As context for the sampling methods described in this report, I first review the use of high resolution photography (HRP) in terms of cost and technological limitations as well as the accuracy of photo-interpreted stand structure measurements in relation to that of standard field measurements. Following that I review standard field sampling methods used to assess forest stand structure. As the intent of these methods were to sample forest stand structure (trees, snags, and downed wood) in boreal Ontario, this brief review focuses on stand structure and applicable measurements and is restricted to publications reporting from North American boreal forest landscapes.

High-resolution aerial photography

Changes in cost and technical considerations

High resolution photographs are most often acquired using helicopters rather than fixed-wing aircraft. Helicopters have more flexibility in landing locations (Bradatsch 1980), for example to reload cameras (Rhody 1977, Hall 1984), require less than half the visibility distance of fixed-wing aircraft (Rhody 1977), and are capable of the low speeds needed to minimize image motion, allowing for larger-scale photo acquisition (Hall 1984). Although helicopter photo capture was historically considered too costly and its use often limited unless combined with other activities (Avery 1958, 1959), a study estimating tree volume reported that photo plot costs were only 15 to 16% of field plot survey costs in easily accessible field plots (Lyons 1967). When these photo plots were combined with a sub-sample of field plots needed for error assessment, costs were still only 55 to 58% of collecting the same data using field plots alone (Lyons 1967). Limitations of weight and space for photographer and equipment were also an issue early on (Avery 1959), but a major limitation of HRP capture initially was the difficulty in precisely determining photo scale due to the inability to accurately measure altitude (using barometric altimeters) unless ground control points were available (Avery 1958, 1959; Kippen and Sayn-Wittgenstein 1964). Thus, photo scale would be increasingly inaccurate with decreasing height aboveground at which photos were taken. Today, this limitation has been overcome with the development of laser altimeters, which are precise to within 1 cm (Wiskair Helicopters, pers. comm.).

Historically, black and white photos were often used but provided poor images, especially when overcast conditions limited the shadows (Avery 1958). Use of colour film was restricted due to its limited latitude of exposure and high processing costs (Avery 1959). Colour photos were useful, however, for tree species identification, especially to differentiate hardwood species (Avery 1959). Regardless of film type, film had to be changed frequently (e.g., after 12 exposures) and exposure settings had to be checked after each exposure (Avery 1958). Today, depending on film type and application, fewer stops are required to change film rolls and exposure among shots is controlled automatically. Prior to the availability of GPS technology, capturing photos at precise ground locations required marking flight paths on maps or aerial photographs (Bradatsch 1980) and pre-marking plot perimeters or plot centres on the ground to facilitate helicopter navigation (Avery 1958, Lyons 1964), reducing the advantages associated with this technology.

The advent of GIS technology and more advanced photographic equipment has increased the feasibility of using HRP for forest sampling. Some advantages of sampling forest structure using HRP include:

- the ability to sample a large number of plots in a short period of time in a predetermined distribution pattern
- the ability to sample in remote, otherwise inaccessible, areas
- a permanent record that can be reinterpreted at any time
- the minimal amount of field sampling required to assess photo-interpretation error
- the ability to sample at any time of the year, depending on study objectives, weather, and aircraft availability.

Considerations for successful photo-capture include ensuring optimal timing to satisfy project objectives (e.g., prior to leaf-fall to assess post-fire status (live or dead) of deciduous standing structure), targeting ideal weather conditions (i.e., under light overcast; Dendron Resource Surveys 1988) to provide optimal photos for interpretation, considering effect of time of day (i.e., late morning/early afternoon vs. early morning/late afternoon to minimize excessive shadowing from standing structure; Croft et al. 1981), and taking photographs at an altitude to allow accurate photo-interpretation of targeted attributes and coverage of twice the width of the plot diameter

to minimize photo centre to edge lens distortion (e.g., Paine and Kiser 2003:35).

Accuracy of photo-interpretation

An important consideration in relying on aerial photographs for field sampling is the error rates associated with photo-interpretation. These errors are often separated into those related to detection and classification as follows:

- Detection errors occur when the interpreter misses structure in the photograph that exists in the field (an error of omission) and when they detect structure in the photograph where it does not exist in the field (an error of commission).
- Classification errors occur when 'detected' structure is incorrectly classified; for example, a tree is identified as a snag, a hardwood is identified as a conifer, or the structure is assigned to the wrong diameter or height class.

Interpretation errors can be minimized by considering for example the time of year that photos are taken. Photo capture during the period when hardwoods are without leaves and in spring vs. autumn (larger sun angles) creates greater image displacement allowing for more accurate direct measurements of tree diameter and height (Avery 1959, Hall and Aldred 1992). Having snow present is not recommended as too much light may mask areas that should be dark causing, for example, stems and branches to appear thinner or disappear altogether (Kippen and Sayn-Wittgenstein 1964). Although no published material was found, the shape of the sample plot used may influence interpreter error through a potential edge effect. The perimeter to area ratio, a measure of edge effect, is 2.4:1 for a circular plot vs. 2.7:1 for a square plot and 3.3:1 for a rectangular or strip plot (Thompson et al. 1998:44). As an example, a circular plot would likely have more structure (e.g., trees) within the plot than bordering the perimeter as compared to a rectangular plot thus reducing potential detection errors on the plot perimeter.

Specific errors identified in studies that have used photos to detect stand structure are mainly detection errors attributed to the size of the structure being assessed. For example, standing structure not detected by photo-interpreters often includes progressively shorter trees (Kippen and Sayn-Wittgenstein 1964, Aldred and Kippen 1967, Bradatsch 1980, Hall 1984, Hall and Aldred 1992, Chapman and Cole 2006), trees in dense patches or clumps (Needham and Smith 1987), shorter snags (Chapman and Cole 2006, Dendron Resource Surveys 1995), and snags present among many trees (Dendron Resource Surveys 1995). Downed wood may not be detected due to its small size (Muraro 1970, Dendron Resource Surveys 1981), its location under a forest canopy (Dendron Resource Surveys 1997) or amongst a number of standing trees (Dendron Resource Surveys 1981), or because it is covered with other downed wood (Lyons 1967). Downed wood counts were consistently underestimated among plots in a post-fire study reported by McCleary (2005) who suggested that a lower flying height might decrease error rates (~1:1,800 contact scale aerial photos were interpreted).

Accuracy of tree species identification from high resolution photos is reported to be high, ranging from 73 to 100% (Kippen and Sayn-Wittgenstein 1964, Aldred and Kippen 1967, Bradatsch 1980, Needham and Smith 1987, Chapman and Cole 2006), with error rates increasing for smaller trees (Kippen and Sayn-Wittgenstein 1964). Chapman and Cole (2006) reported correct classification of snags to a specific form class (i.e., poplar, other hardwood, pine, other conifer) for 93% of 56 snags. Dendron Resource Surveys (1995) reported that of the snags detected, only 3% were misclassified between standing and fallen material.

Another source of error during photo-interpretation is measurement techniques. For example, when using HRP for sampling forest structure, tree diameter is often estimated using species-dependent diameter–tree height–crown area regressions that predict diameter from photo measurements of tree height and crown area (Aldred and Kippen 1967, Lyons 1967, Hall et al. 2001). Thus, accuracy would depend on the validity of the prediction equations. Diameter measurements have also been estimated from photos using a mil scale to measure visible boles (Avery 1959) or by measuring stem shadows (Kippen and Sayn-Wittgenstein 1964). The accuracy of both techniques relies on interpreter experience and consistency. Differences between field and interpreted measurements of tree diameter using a mil scale have been shown to range from 0.5 cm to 6.4 cm (Avery 1959) while stem shadows provided diameter measurements accurate within 3.8 cm (Kippen and Sayn-Wittgenstein 1964). Both methods require tree boles to be visible at 1.3 m, which may limit their consistent use among plots throughout a study. Visibility is also a consideration for downed

wood assessments. For example, interpreted downed wood lengths were overestimated under canopies but mean diameter and length of downed wood were similar to field measurements in clearcuts (Lyons 1967).

All of the above underscores the importance of including a subset of field plots to assess error in any study that relies on HRP to sample forest structure.

Field plot sampling

One of the challenges of field sampling is achieving sufficient sample size, which can be restricted due to time, resources, and/or access. Since fires in boreal forests are often large and inaccessible, sampling of post-fire residual structure can be limited, for example, to portions of the fire. A review of the literature indicated that where plots were used to sample residuals and fire size(s) was reported, the number of plots sampled per 1000 ha of fire area was remarkably consistent, ranging from 0.1 – 10.9 plots per 1,000 ha of fire (Viereck and Dyrness 1979, Hansen 1983, Schulte and Niemi (1998), Kemball (2002), Pedlar et al. (2002), Simon et al. (2002), Stuart-Smith et al. (2002), Wang (2002), Hely et al. (2003), Nappi et al. (2003), Stambaugh (2003), Stepnisky (2003), Haeussler and Bergeron (2004), Harper et al. (2004), Kurulok (2004), Saint-Germain et al. (2004)).

In general, methods for sampling forest stand structure are well documented (e.g., Bookhout 1994) but the focus is on field sampling methods. As discussed above, a review of the literature revealed that field sampling is the only approach documented to date for sampling post-fire residual structure and most used plot-based sampling (Table 1). The most commonly reported unit of measurement for quantifying post-fire trees and snags was density (number per unit area), while units used to measure downed wood varied (Table 2). Not only did studies vary widely in how they measured the structure, what they measured also varied. For example, the minimum diameter of structure sampled ranged from not reported, to none, to greater than 10 cm, with most studies using a 1 to 10 cm diameter minimum (Figure 1).

Field sampling can provide data that cannot be captured through interpretation of aerial photography. Some measurements relevant to post-fire residual structure studies include, for example, snag and

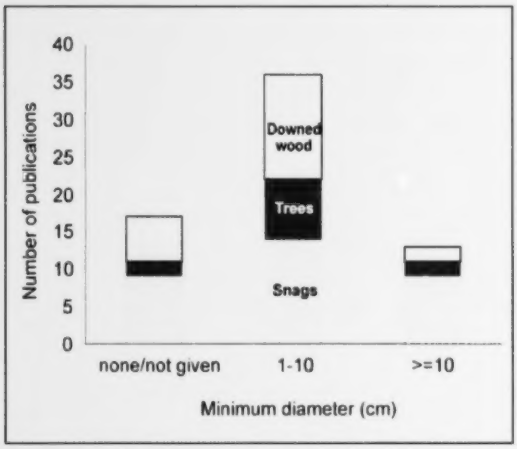


Figure 1. *Minimum diameter (cm) of trees (n = 12 publications), snags (n = 32), and downed wood (n = 22) measured in studies on post-fire residual structure in boreal forests reported in the literature.*

downed wood decay classes which are important in wildlife habitat studies (Drapeau et al. 2002, Nappi et al. 2003, Stambaugh 2003) and in measuring the carbon in downed wood (Bond-Lamberty et al. 2003).

Study area

The study area is the boreal and the northern portion of the Great Lakes-St. Lawrence forest region of Ontario (Rowe 1972), which is dominated by black spruce (*Picea mariana* Mill. BSP) and jack pine (*Pinus banksiana* Lamb.) forest cover types but includes aspen (*Populus* spp.) and paper birch (*Betula papyrifera* Marsh.), as well as red pine (*Pinus resinosa* Ait.) and white pine (*Pinus strobus*) in the more southern areas. Current forest cover is the result of a combination of forest harvesting and periodic fire and insect disturbances.

Climate in the study area is humid continental with a temperature decreasing along a north south gradient and precipitation decreasing along a southeast to northwest gradient (Baldwin et al. 2000). Soils vary but are dominated by brunisols in the northwest part of the province, and luvisols and gleysols in the Claybelt area in the northeast (Baldwin et al. 2000).

Table 2. *Units of measurement used in publications reporting on post-fire stand structure within 20 years of a fire occurring in North American boreal and near-boreal forest. Numbers of non-duplicating publications are in parentheses.*

Units of measurement by publication	Structure sampled		
	Trees (n = 11)	Snags (n = 31)	Downed wood (n = 17)
Density (n = 20)	Harper et al. 2004 Imbeau et al. 1999 Kurulok 2004 Schulte and Niemi 1998 Stambaugh 2003 Stuart-Smith et al. 2002 Viereck and Dyrness 1979	Awada et al. 2004 Ferguson and Elkie 2003 Hansen 1983 Harper et al. 2004, 2005 Imbeau et al. 1999 Kurulok 2004 Larivee 2003 Lee and Crites 1999 LeGoff and Sirois 2004 Miyanishi and Johnson 2002 Nappi et al. 2003 Sander 2003 Schulte and Niemi 1998 Simon et al. 2002 St. Germaine et al. 2004 Stambaugh 2003 Stuart-Smith et al. 2002 Viereck and Dyrness 1979 Wang 2002	Larivee 2003 St. Germaine et al. 2004
Basal area (n = 10)	Apfelbaum and Haney 1981 Hauessler and Bergeron 2004 Hobson and Schieck 1999 Kemball 2002	Apfelbaum and Haney 1981 Drapeau et al. 2002 Ferguson and Elkie 2003 Haeussler and Bergeron 2004 Harper et al. 2005 Hobson and Schieck 1999 Kemball 2002 Lavoie 2004 St. Germaine et al. 2004 Wang 2002	Not applicable
Volume (n = 19)	none	Bond-Lamberty et al. 2003 Manies et al. 2005 Ohmann and Grigal 1979 Pedlar et al. 2002	Harper et al. 2005 Hobson and Schieck 1999 Kemball 2002 Kurulok 2004 Lee and Crites 1999 Pedlar et al. 2002
Transect counts (n = 3)	none	Graf et al. 2000	Graf et al. 2000 Harper et al. 2004, 2005
Mass per hectare (n = 4)	none	none	Bond-Lamberty et al. 2003 Haeussler and Bergeron 2004 Lavoie 2004 Manies et al. 2005
Percent cover (n = 5)	none	none	Capar 2004 Hansen 1983 Kurulok 2004 Lavoie 2004 Morissette et al. 2002

Sample fires

Selecting candidate fires

Candidate fires were selected for sampling from all possible fires that burned in 2005 across Ontario's boreal and near-boreal forest (Rowe 1972). Since the primary objective was to quantify post-fire residual structure, it was important to have information about pre-fire forest structure, such as forest cover type (OMNR 2000)[1] and disturbance history[2] , and to sample unsuppressed fires. Criteria used to assess the suitability among potential fires were (Figure 2):

- availability of fire information: cause, location, size and suppression activity
- availability of forest stand information: cover type and disturbance history
- level of fire suppression activity: not suppressed or large areas within perimeter not affected by suppression activity
- extent of pre-fire human disturbance: no recent forest harvest activity preferred
- fire size: range of sizes desired

In addition to the above criteria, operational considerations required to accommodate HRP sampling were location of fires in relation to:

- proximity of HRP equipment landing and re-fuelling sites
- proximity among fires

The occurrence, location and size of fires were monitored weekly from April through August, 2005, using the OMNR Daily Fire Operations Support System (DFOSS).

Depending on the location and size of the fire, the OMNR has the fire perimeters mapped on the ground or from aircraft using a global positioning system (GPS).

Thus, fire perimeters (in the form of ESRI shapefiles) for fires larger than 40 ha, the smallest fire mapped by the OMNR, were available soon after fires were considered under control or extinguished.

Although unsuppressed fires were preferred for sampling post-fire structure, these were not common. Thus, information on suppression activities was obtained from the OMNR District Fire personnel to determine if unsuppressed areas within suppressed fires were suitable. Suppression activities included areas subjected to heavy initial fire attack (i.e., water bomb drops), areas of burnout (i.e., burning of forest ahead of the fire front) and firebreaks.

If the entire area of a fire satisfied all of the above criteria, the entire fire was considered suitable for sampling. For other potential fires, areas not satisfying the above criteria were removed from the potential sample area along with a minimum 100 m buffer. The remaining area was then considered suitable for sampling but only the largest contiguous area was sampled in each fire.

Details of sample fires

Of the candidate fires, eleven fires were selected for sampling post-fire residual structure across boreal Ontario. These fires burned between late May and early August, 2005, and varied in size from 60 to13,623 ha (based on the OMNR's fire perimeter) (Figure 3, Table 3). Relative fire intensity varied from moderate to extreme based on the Fire Weather Index (FWI), which is a numerical rating of fire intensity (where low <3.0, moderate 3.0 – 9.9, high 10.0 – 22.9, extreme 23.0+) that combines Initial Spread Index – a numerical rating of expected rate of fire spread – and the Buildup Index – a numerical rating of the total amount of fuel available for combustion (Forestry Canada 1992, Hirsch 1996).

The area suitable for sampling post-fire structure within each fire, which amounted to 41 to 6,734 ha (Table 3), varied from the total burned area either due to the exclusion of areas subject to anthropogenic disturbances such as fire suppression activity and/or areas with forest harvest activity within the last thirty years.

[1] Ontario Ministry of Natural Resources' Forest Resource Inventory database except for fires in Quetico Park (see Appendix I)

[2] From OMNR district and forest industry records

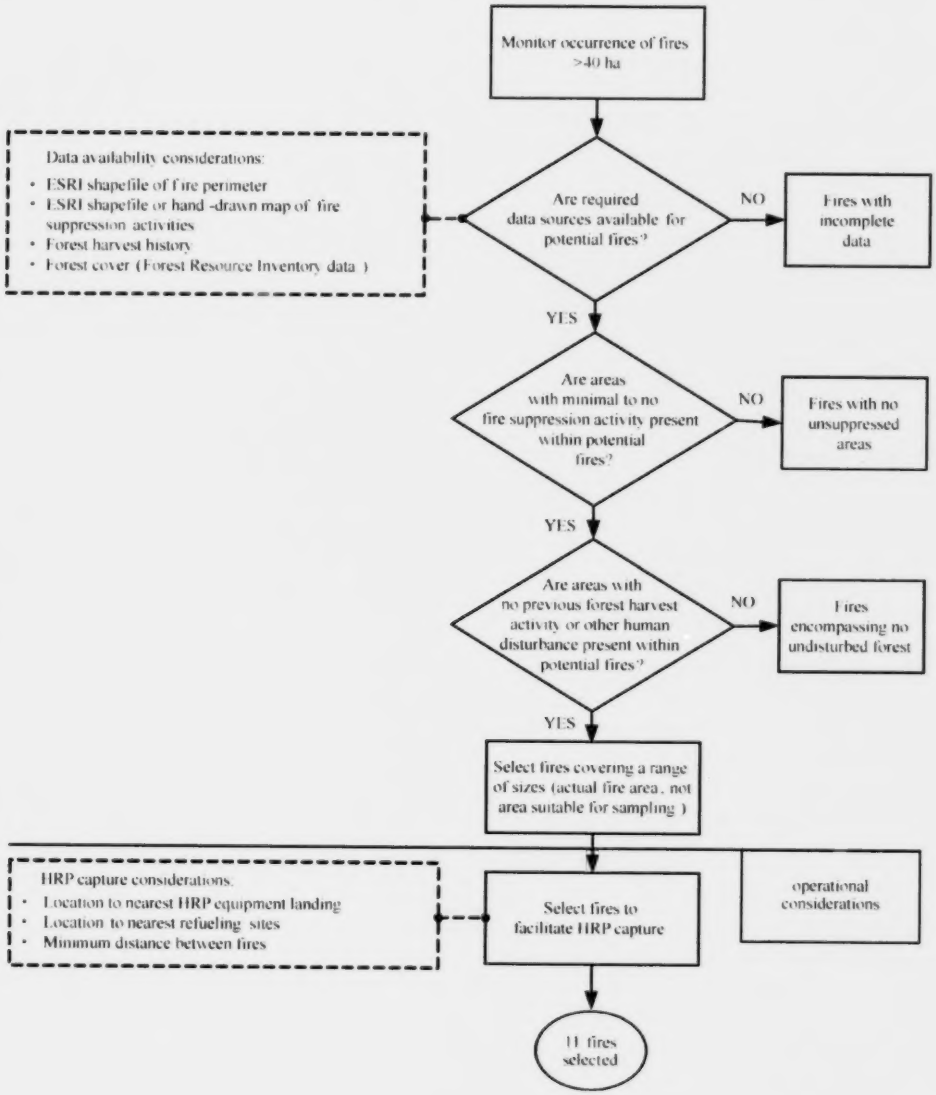

Monitor occurrence of fires >40 ha
Data availability considerations:
• ESRI shapefile of fire perimeter
• ESRI shapefile or hand -drawn map of fire suppression activities
• Forest harvest history
• Forest cover (Forest Resource Inventory data)
Are required data sources available for potential fires?
NO
Fires with incomplete data
YES
Are areas with minimal to no fire suppression activity present within potential fires?
NO
Fires with no unsuppressed areas
YES
Are areas with no previous forest harvest activity or other human disturbance present within potential fires?
NO
Fires encompassing no undisturbed forest
YES
Select fires covering a range of sizes (actual fire area, not area suitable for sampling)
HRP capture considerations:
• Location to nearest HRP equipment landing
• Location to nearest refueling sites
• Minimum distance between fires
Select fires to facilitate HRP capture
operational considerations
11 fires selected

Figure 2. *Process used to select candidate fires for sampling post-fire structure.*

High resolution aerial photography sampling methods

Within fires, high resolution photographs were used to sample post-fire residual structure in early September, 2005, within 1 to 4 months after the fires burned and prior to deciduous leaf fall to differentiate between live and dead trees (Hely et al. 2003). The process of establishing the sample plot network, and capturing and interpreting the HRP plots, is described below.

Sample point layout within sample fires

Sample point locations were established across the area available for sampling within each fire using a series of GIS (Geographic Information System; ArcMap 9.0©) data layers, including the OMNR fire perimeter, pre-fire forest cover, fire suppression information and forest harvest history (as discussed above). Unburned forest patches (i.e., insulars and peninsulars) were mapped (Buchanan Forest Products) across the largest fire (NIP-20) allowing the sampling points to be more efficiently distributed among burned areas. Sample points were placed 300 (minimum distance required between sample points along transects to allow cameras to reload) to 600 m apart along east-west transects spaced 200 to 400 m apart (Figure 4). Points along transects covered a range of distances from fire edge (Table 4). Points were also located at varying distances and varying orientations (e.g., leeward of fire direction) from natural firebreaks such as creeks, alder swales and lakes, and unburned areas within the fire perimeter (if information was available).

Figure 3. *Location of 11 fires sampled using high resolution aerial photography (HRP) in northern Ontario, Canada.*

Table 3. *Start date, cause, location, size, sampled area, and estimated intensity of 11 sample fires from 2005 fire season in Ontario, Canada.*

Fire ID	Fire start date	Cause of fire	Latitude[a]	Longitude[a]	Fire area (ha)	Sampled fire area (ha)	FWI[b]
TIM-5	May 26	Railway	50.581	-88.744	440	306	16
TIM-7	May 26	Misc.	50.293	-88.776	449	214	13.7
COC-10	May 26	Railway	49.452	-81.131	350	347	33
NIP-20	Jun 20	Lightning	48.273	-80.778	13,623	6,734	26.8
TIM-19	Jul 14	Lightning	50.176	-89.710	3,200	146	26.4
CHA-18	Jul 17	Lightning	48.302	-82.922	60	41	34.1
FOR-14	Jul 22	Lightning	47.767	-81.794	430	430	13.8
THU-30	Jul 24	Lightning	48.293	-91.659	429	379	11.4
THU-31	Jul 24	Lightning	48.177	-91.371	1,428	1,229	11.4
FOR-24	Aug 05	Lightning	48.190	-82.230	213	213	8.8
THU-67	Aug 06	Lightning	50.545	-87.981	2,325	969	12.4

[a] Coordinates based on 1983 North American Datum.
[b] The FWI (Fire Weather Index) is a numerical rating of fire intensity (low <3.0, moderate 3.0 – 9.9, high 10.0 – 22.9, extreme 23.0+) that combines the ISI (Initial Spread Index - a numerical rating of expected rate of fire spread) and the BUI (Buildup Index - a numerical rating of the total amount of fuel available for combustion) (Forestry Canada 1992, Hirsch 1996).

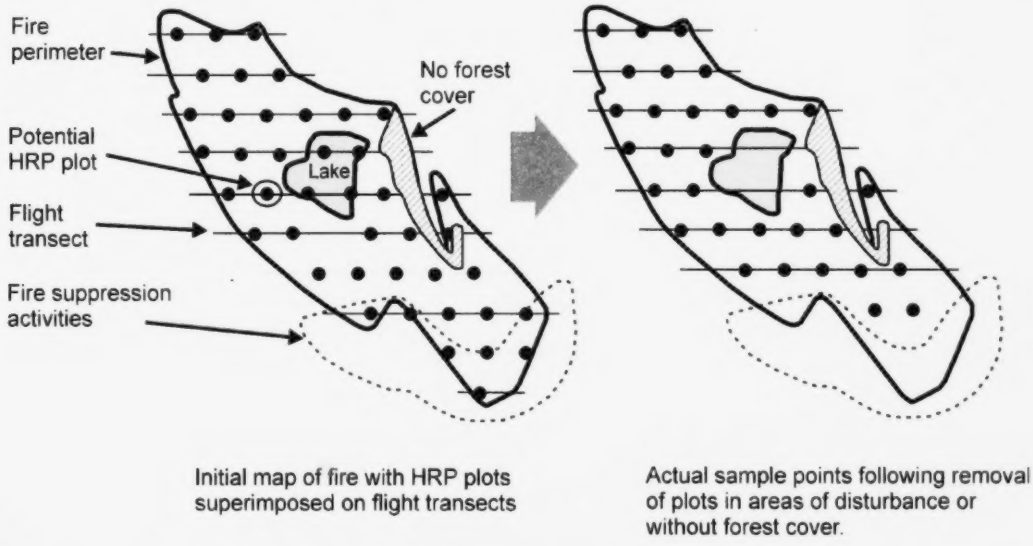

Fire perimeter
No forest cover
Potential HRP plot
Lake
Flight transect
Fire suppression activities
Initial map of fire with HRP plots superimposed on flight transects
Actual sample points following removal of plots in areas of disturbance or without forest cover.

Figure 4. *Sample HRP plot layout within a hypothetical fire. (Maps of all 11 sample fires showing final plot layouts are provided in Appendix II) Table 4. Distribution of HRP sample plots by distance to MNR fire perimeter (nearest contiguous unburned forest or drainage feature) for each sample fire.*

The resulting ESRI shapefile of sample points for each fire was provided to the photo-capture contractor who programmed them into a GPS (LANDSTAR Mark IV Surveyor) and preflight-tested to ensure they met all operational considerations. The latter include distance between sample points (minimum 300 m), distance to nearest landing location to reload film (maximum 60 photo pairs per roll), and distance to nearest refueling location.

HRP data capture

High resolution photographs were captured using 2 Hasselblad MK-70 cameras mounted 6.1 m apart on a 7-m-long helicopter boom mounted under a helicopter (Figure 5). A GPS system integrated with the cameras ensured that cameras were automatically triggered within 5 m of the planned photo capture points. Thus, the centre of the rear photo (base photo for interpretation) was always within 5 m of the planned plot centre, except in few instances where head winds were exceptionally high or planned points were over water. The latter were moved at the discretion of the pilot.

Data collected at the time of photo capture included the coordinates of photo centre (rear photo), the time of photo capture, and helicopter orientation, ground speed, and height aboveground. Portrait grade colour film capable of at least 60 exposures per roll was used (film specifications for optimal photographic quality is described elsewhere, e.g., Goba et al. 1982, Pitt 1994). Film contact scale ranged from 1:900 to 1:1,200 across capture heights of 92 to 120 m (Table 5) so photo scale was calculated independently for each plot.

When required, film reloading was made possible by landing at airports or helipads (preferred) or on old roads or cutovers as long as levels, dry, clean area was available (Wiskair Helicopters, pers. comm.). When digital camera technology becomes commonplace for aerial photography, the constraint of having to reload cameras will be alleviated.

Overall ferry time (i.e., time spent flying between sample fires) was 10.1 hours and photo capture time (i.e., time spent capturing photos within sample fires) was 17.1 hours for 739 photo points in 11 sample fires. Sampling fires within three general areas (Figure 3) helped to minimize ferry time.

Prior to interpretation all photographs were enlarged by a factor of 2.45 to produce 15.2 x 15.2 cm (6 x 6 inch) photos with scales ranging from 1:367-1:490 (Table 5).

Table 4. *Distribution of HRP sample plots by distance to MNR fire perimeter (nearest contiguous unburned forest or drainage feature) for each sample fire.*

Fire ID	Number of HRP sample plots by distance from MNR fire perimeter					
	<50 m	50-99 m	100-149 m	150-199 m	200+ m	Total
TIM-5	4	4	3	3	19	33
TIM-7	7	6	5	3	2	23
COC-10	5	5	5	5	11	31
NIP-20	3	9	11	12	288	323
TIM-19	4	4	4	3	2	17
CHA-18	4	4	2	2	1	13
FOR-14	6	6	5	4	17	38
THU-30	12	10	7	3	2	34
THU-31	7	8	7	7	82	111
FOR-24	7	4	3	1	5	20
THU-67	0	0	0	4	92	96
Total	59	60	52	47	521	739

Figure 5. *Wiskair Bell Long Ranger helicopter used to capture HRP photos shown with camera boom attached. Cameras are mounted 6.1 m apart within the boom. (Photo courtesy of WiskAir Helicopters, Thunder Bay, Ontario)*

Table 5. *Camera equipment and details related to capture and processing of sample plot data to sample post-fire residuals.*

Camera system	2 Hasselblad MK-70s mounted 6.1 m apart on a helicopter-mounted boom
Lens focal length	100 mm
Film specifications	ASA colour portrait 70 mm (actual image = 62.2 mm)
Film contact scale	1:900 – 1:1,200
Photo capture height (above ground level)	92 – 120 m; height measured using a laser altimeter (recorded at 0.1 m intervals; precise to 0.01 m)
Navigational aid	LANDSTAR Mark IV Surveyor GPS system
Photo enlargement factor	2.45
6 × 6 inch photo scale	1:367 – 1:490
Ground width of enlarged photo	56 – 75 m

Photo-interpretation

Of the 739 photos captured, 79 were not interpreted because they fell within unburned forest, unforested areas (e.g., wetland), or areas with anthropogenic disturbance (e.g., pre-fire logging activity). The remaining 660 photos were interpreted by a single photo-interpreter to eliminate among-interpreter error.

The 15.2 by 15.2 cm (6 by 6 inch) photos were at a scale of 1:367 to 1:490, covering a ground area ranging from 56 by 56 m to 75 m by 75 m. Interpretation was semi-automated through the use of RMAP™ software (adapted from software developed by Pitt (1994)). For each photo pair, the flight information, including image identification, altitude, and orientation, was entered into the software, which then automatically calculated photo scale and determined location of the 0.05 ha circular plot (25.2 m diameter), which was used as the base photo for interpretation. Sample plots were centred over the rear photo (Figure 6), with approximately 90% front and rear photo overlap.

Using a digitizing tablet and a mirror stereoscope with 3X binoculars (Sokkia MS27©) (Figure 7), the interpreter systematically assessed the structure on each photo beginning at the centre and moving towards the edge, usually starting at the top right and moving around the photo until all structure was tallied. The software controlled the plot boundary based on the height above ground of photo capture and only standing structure (live trees and snags) within the plot could be interpreted. Downed wood could be interpreted even if outside the plot boundary. The software also assigned each piece of structure a unique identifying number to associate it with a particular plot.

For the purposes of this sampling, we defined live trees as standing stems (≤45° lean) more than 2 m tall having at least some green foliage. Snags were defined as stems with the same characteristics as live trees but with no green foliage. Downed wood was defined as stems lying on the ground or with >45° lean and with at least 75% of the length on or above ground (to minimize the amount of pre-fire downed wood tallied).

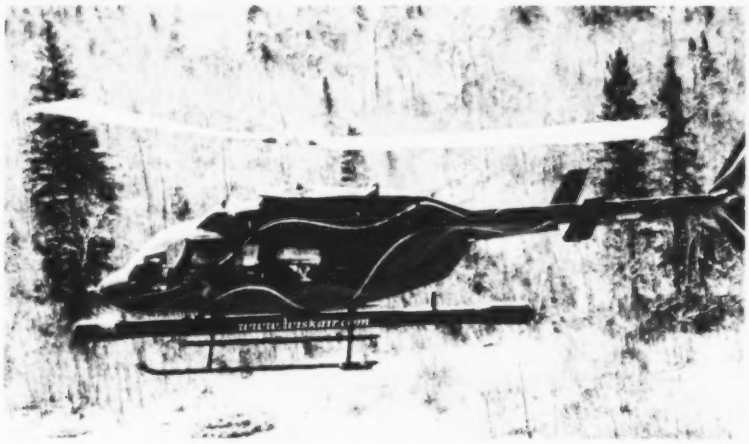
For live trees, heights of dominant and codominant stems were estimated using a parallax bar. Only trees ≥2 m were tallied. For each tree in the plot, the interpreter first identified the species, then marked the crown centre to determine its spatial coordinates and then marked the crown edges. From these measurements, the software calculated crown diameter and, using species-specific tree height/crown area regression equations (RBCormier©), estimated stem diameter at breast height.

For snags, heights of dominant and codominant stems were estimated using a parallax bar. Only snags ≥2 m were tallied. For each snag, the interpreter first identified the cover class (conifer or hardwood) and then marked the crown centre (if visible) or the top of the stem to determine its spatial coordinates. Since crown area could not be used to estimate stem diameter, a mil scale or scale-specific template (which varied by altitude of photo) was used to assign each snag to one of three diameter classes (<10 cm, 10-24.4 cm, ≥24.5 cm).

For downed wood, the interpreter marked each end of the structure to determine its spatial coordinates with the software dictating where the structure went outside the plot boundary. Similar to snags, diameter of downed wood was assessed at the estimated centre of the downed wood piece using a mil scale template.

A summary of measurements obtained for each type of residual structure is provided in Table 6. For each photo plot, two geo-referenced ESRI shapefiles were created: one for standing structure (trees and snags) and another for downed wood. Species codes used by the interpreter are provided in Appendix I and III and examples of data file contents and structure resulting from HRP interpretation are provided in Appendix IV).

Figure 6. *Sample rear (base) photo showing photo identification (yellow numbers on left border) sample plot perimeter (red circle) and centre of rear photo (red plus), which is also the centre of 0.05 ha circular plot.*



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For the purposes of this sampling, we defined live trees as standing stems (≤45° lean) more than 2 m tall having at least some green foliage. Snags were defined as stems with the same characteristics as live trees but with no green foliage. Downed wood was defined as stems lying on the ground or with >45° lean and with at least 75% of the length on or above ground (to minimize the amount of pre-fire downed wood tallied).

For live trees, heights of dominant and codominant stems were estimated using a parallax bar. Only trees ≥2 m were tallied. For each tree in the plot, the interpreter first identified the species, then marked the crown centre to determine its spatial coordinates and then marked the crown edges. From these measurements, the software calculated crown diameter and, using species-specific tree height/crown area regression equations (RBCormier©), estimated stem diameter at breast height.

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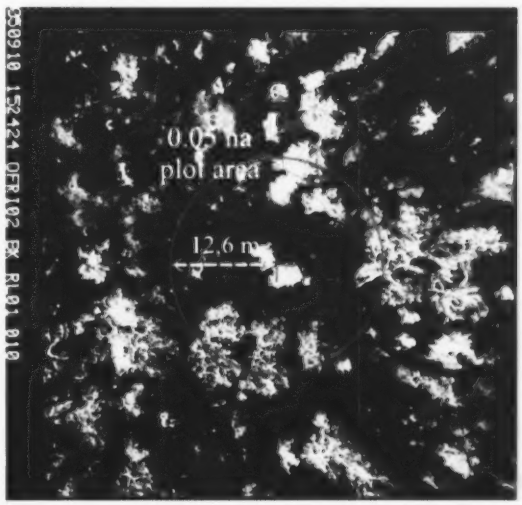
A summary of measurements obtained for each type of residual structure is provided in Table 6. For each photo plot, two geo-referenced ESRI shapefiles were created: one for standing structure (trees and snags) and another for downed wood. Species codes used by the interpreter are provided in Appendix I and III and examples of data file contents and structure resulting from HRP interpretation are provided in Appendix IV).



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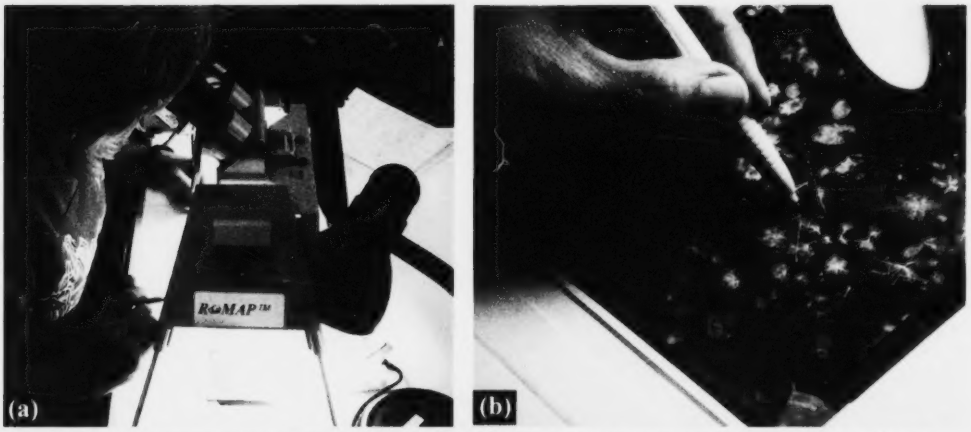

Figure 7. *Photo-interpreter using a mirror stereoscope with binoculars (a) to interpret post-fire stand structure (b) on a sample photo.Table 6. Summary of variables measured for post-fire residual live trees, snags, and downed wood during interpretation of HRP plots.*

Table 6. *Summary of variables measured for post-fire residual live trees, snags, and downed wood during interpretation of HRP plots.*

Structure and variable	Note
Trees	**Minimum 2 m height**
Species	Only tree species are included
Height	Heights are determined for each canopy position (see below) prior to interpretation within each plot
Crown diameter	Average of longest and shortest crown distance OR east-west and north-south crown distance
Canopy position	Dominant, codominant, intermediate, suppressed
Diameter at breast height (dbh)	Species-diameter-tree height-crown area regressions
Geographic coordinates	Latitude/longitude and UTM (NAD83 datum) at crown centre
Snags	**Minimum 2 m height**
Cover class[a]	Conifer or hardwood
Height	Heights are determined for each canopy position (see below) prior to interpretation within each plot
Canopy position	Dominant, codominant, intermediate, suppressed
Dbh class[a]	<10 cm, 10 – 24.4 cm, ≥24.5
Geographic coordinates	Latitude/longitude and UTM (NAD83 datum) at crown centre or top of existing portion of bole
Downed wood	**At least 75% of the length must be clearly lying on or above the ground surface; total minimum 2 m length**
Length	Minimum 2.0 m length inside plot perimeter
Diameter class[a]	<10 cm, 10 – 24.4 cm, ≥24.5
Geographic coordinates	Latitude/longitude and UTM (NAD83 datum) at both ends of portion of structure lying within plot perimeter

[a] These variables are not programmed into RMAP© software and were manually estimated by photointerpreter.

Field sampling methods

Of the 11 sample fires, four were selected to establish field plots to allow longer-term monitoring of stand structure and error assessment of photo interpretation. These fires were chosen based on their location within parks or protected areas to ensure that the field plots would not be subject to salvage logging and thus could be monitored for a reasonable period post-fire.

Field plot selection and establishment

Potential field plots were selected from the entire set of 660 HRP photos based on the following criteria:

- Live trees present in the sample plot (but not a residual patch >0.25 ha)
- Forest cover types occurring within fire perimeter represented (based on Ontario Forest Resource Inventory database, OMNR 2000)
- Range of stand ages within fire perimeter represented (based on the Ontario Forest Resource Inventory database, OMNR 2000)
- Five to 10% of photo plots sampled within each fire

Among all possible sample plots that met these criteria, final plot locations were chosen based on accessibility.

A total of 50 field plots (Figures 8 a-d) were established in 3 fires north of Thunder Bay, Ontario near Armstrong (THU-30 and THU-67 in Wabakimi Provincial Park and THU-31 in Windigo Bay Provincial Nature Reserve) and one in Quetico Park, Ontario (FOR-14) representing 8% of the interpreted photo plots[3].

Based on a pilot study conducted immediately prior to this work and studies in recently harvested areas with high densities of downed wood (e.g., Lyons 1967, Dendron Resource Surveys 1981), photo-interpreter error in detecting and measuring downed wood was expected to be lower than that for standing structure. Given this as well as the relatively longer time it takes to measure the log lengths and diameters (in comparison to measuring trees and snags), downed wood was sampled in a subset of 30 of the 50 field plots, or 4.5% of all photo plots interpreted.

As increasing forest cover may affect downed wood detection, plots covering a range of live tree occurrence were selected for downed wood assessments. Similarly, the abundance of downed wood may affect its detection, thus downed wood sample plots were selected to cover a range of stand ages from 65 to 165 years, assuming that would equate to a range of densities and thus a range of downed wood abundance.

Field plots were 0.05 ha or 500 m^2 circular plots (Figure 9) established in the exact location of the photo interpreted plots. Establishment involved 2 major steps: the location of plot centre for the corresponding photo plot and establishment of plot perimeter. A GPS unit with plot centres programmed into it was used by field crews to get within 3 to 5 m of the plot centre. Landmarks (large trees, snags, logs or anything distinctive; e.g., 2 logs criss-crossed) were then located on the photo and used to identify plot centre on the ground.

At each plot, a 1-m-long metal stake was driven into the ground approximately 20 – 30 cm deep to mark the plot centre. If that was not possible, a shorter stake was used and secured using a rock cairn. An aluminum tag indicating the plot number was securely affixed to the stake and buried in the ground to protect it from animals/birds. The plot perimeter (circular plot with radius of 12.6 m) was temporarily marked in one of two ways. The first was used when residual structure was sparse and involved using a 12.6-m-long rope with a loop in one end. The looped end was placed around the centre stake and run outwards in as many directions as possible until the plot perimeter was clearly outlined with marking paint. For structure on or very close to the plot perimeter, the rope was used to confirm whether it fell in or out of the plot. Structure was considered to fall within the plot if at least one half of a tree or snag or if 2 m or more of the length of downed wood was within the plot perimeter. The second method of marking the plot perimeter involved using a vertex unit (Vertex III with T3 transponder, manufactured by Haglof Sweden AB; www.haglofsweden.com), which was calibrated (for temperature and barometric pressure) prior to and during use to ensure its accuracy in measuring distance. The same general approach was used with the vertex as with the rope, but the vertex method was more effective when residual structure was more abundant. Using either method, a flagged

[3] Research permits are required to conduct any activities in provincial parks and protected areas. These were obtained from parks staff prior to conducting the study and renewed annually to access the plots for remeasurement.

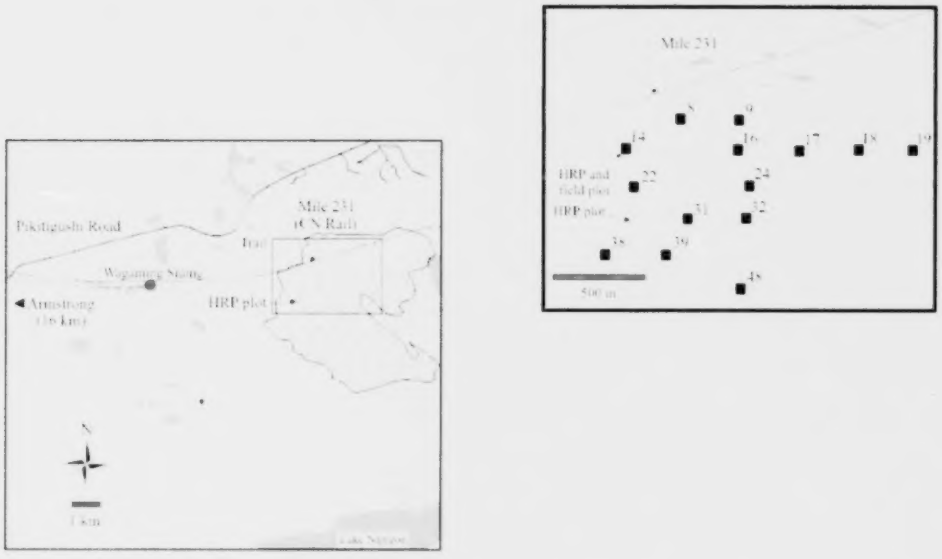

Figure 8a. *Sample fire THU-31 (1,429 ha) (shaded polygon) within Windigo Bay Provincial Nature Reserve showing HRP plots (open circles and solid squares) and field plots (solid squares). (Note: Only plots 9, 14, 16, 17, 18, 19, 22, 24, 31 and 32 were sampled for DWD).*

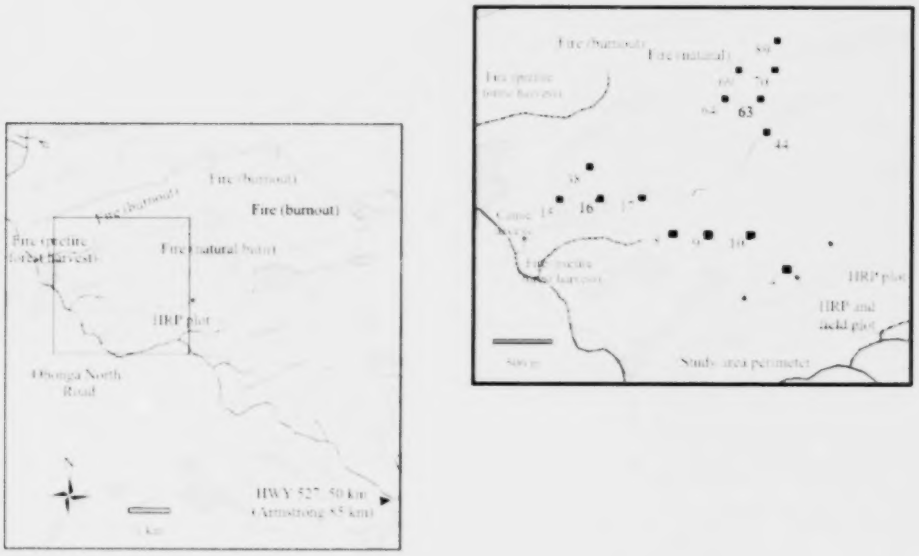

Figure 8b. *Sample fire THU-67 (2,325 ha) (shaded polygon) within Wabakimi Provincial Park showing HRP plots (open circles and solid squares) and field plots (solid squares). Field plot numbers are provided. (Note: Only plots 8, 9, 15, 17, 38, 44, and 63 were sampled for DWD.)*

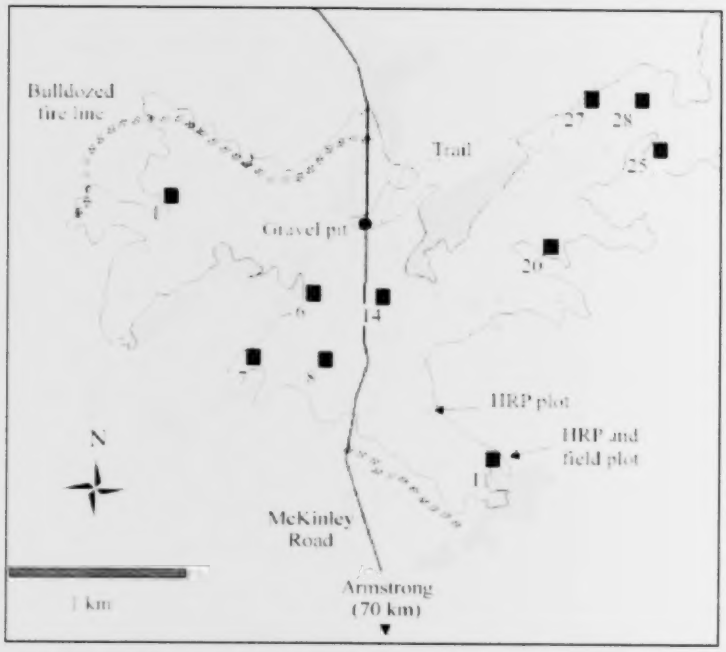

Figure 8c. *Sample fire THU-30 (439 ha) (shaded polygon) lying partially within Wabakimi Provincial Park (east of McKinley Road) showing HRP plots (open circles and solid squares) and field plots (solid squares). (Note: Only plots 6, 11, 25, 27, and 28 were sampled for DWD.)*

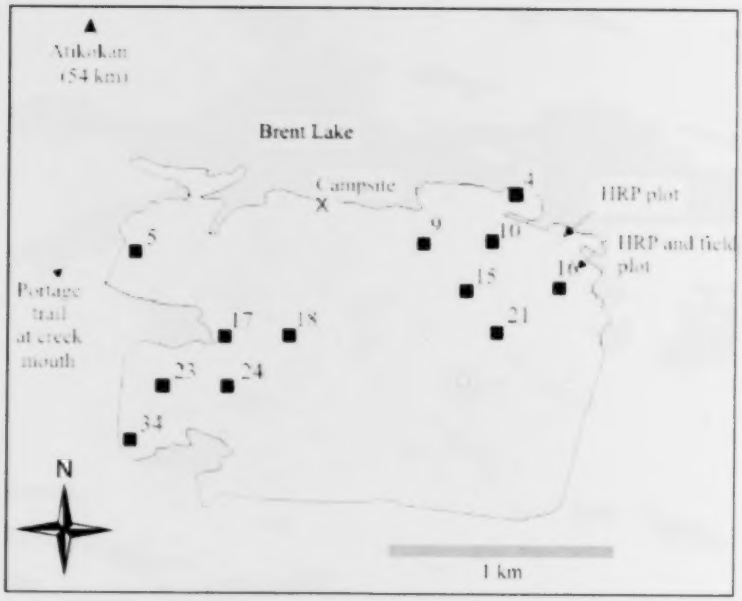

Figure 8d. *Sample fire FOR-14 (430 ha) (shaded polygon) within Quetico Park showing HRP plots (open circles and solid squares) and field plots (solid squares). (Note: Only plots 4, 5, 9, 15, 16, 17, 18, and 21 were sampled for DWD.)*

pin was placed at the 12 m location east and west of the plot centre. This 24 m-long transect would serve as the basis for a forest floor fire severity survey (see below).

Measurement of residual structure

Definitions used for residual structure in the field plots were the same as those applied during photo interpretation. To be included in the data set, standing structure had to be >2 m in height (no minimum diameter) with the stem angled ≥45° from the ground (estimated along portion of structure from where rooted or touching ground to at least the mid-section). If live foliage was present then it was categorized as a tree, otherwise it was included in the snag category. Because the field assessments occurred in late fall in the year of burn, tree and snag status were determined using a combination of the aerial photo (rear) and visual inspection. Unless it was obvious that a tree was dead before the fire, the photo was used to determine if it was a live tree or snag at the time of photo capture. All structure at an angle <45 °, whether rooted or not, was included as downed wood if it had a length of 2 or more metres within the plot boundary (no minimum diameter at centre) and at least 75% of the length was lying on or above the ground surface. The key used to assess structure in the field is provided in Figure 10.

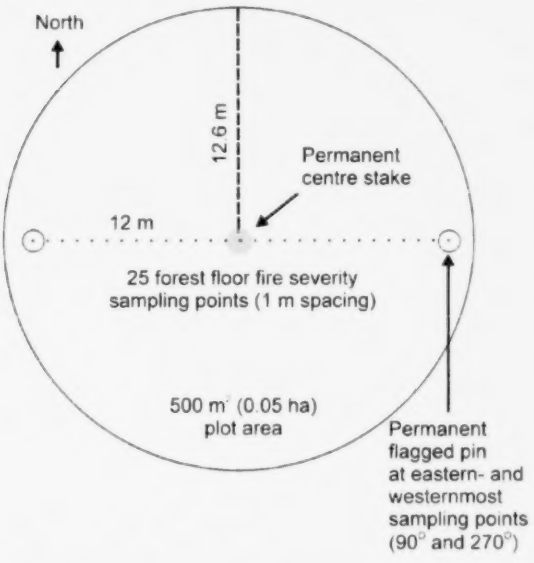
North
12.6 m
Permanent centre stake
12 m
25 forest floor fire severity sampling points (1 m spacing)
500 m² (0.05 ha) plot area
Permanent flagged pin at eastern- and westernmost sampling points (90° and 270°)

Figure 9. *General layout of field plots used to sample post-fire residual structure in this sampling. A 24-m transect was used to sample the forest floor at 25 evenly spaced points.*

In each plot, trees and snags were located in a systematic fashion (e.g., from plot centre towards the plot edge and in a clockwise direction) and given a unique number, which was marked on an enlarged copy (approx. 1:75 to 1:150 scale) of the HRP base photo print. If available at the time of sampling (photo interpretation and field sampling periods overlapped), an enlarged copy of the HRP base photo on which all structure was identified by the photo-interpreter (marked one colour for trees and snags and another colour for downed wood) was used for reference. All trees and snags identified by the photo-interpreter were located on the ground, if present (i.e., not a commission error), and measured. The final step was to record data on all additional trees and snags in the plot (i.e., omission errors). Data sheets used to record field plot data are provided in Appendix V.

Data recorded for residual trees and snags included species and diameter at breast height (Table 7). Diameter at breast height was measured facing away from plot centre, except where the plot was sloped in which case diameter was measured while standing midway up the slope. Secondary observations included stem breakage (i.e., % bole loss), fire damage on trees (tree crown scorch), and snag origin (i.e., pre- vs. post-fire) and decay status (described in more detail below). To indicate that standing structure had been measured, trees were marked with orange or pink tree marking paint sprayed in a line around >50% of the stem circumference at dbh and snags were marked with blue marking paint. A numbered tag was also nailed at breast height to trees >7.5 cm diameter (or loosely wired to smaller trees) for easy identification during future monitoring. To minimize potential tree growth around the tag, they were attached so they would hang away from the bole.

In the 30 plots in which downed wood was assessed, downed wood was located and identified with a unique number on an enlarged copy of the HRP base photo print that included the photo-interpreter's marks. All downed wood identified by the photo-interpreter was located in the field, if present, and measurements recorded (Table 7). A vertex unit (Vertex III with T3 transponder, manufactured by Haglof Sweden AB; www.haglofsweden.com) was used to measure the length of downed wood lying

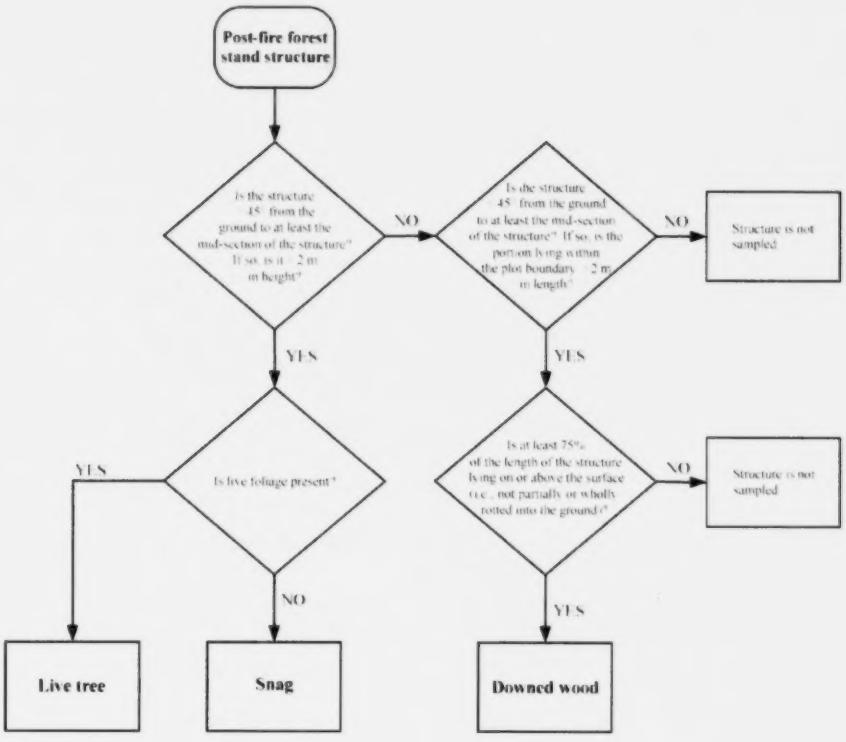
Post-fire forest stand structure
Is the structure ≥45° from the ground to at least the mid-section of the structure? If so, is it ≥2 m in height?
NO
Is the structure ≥45° from the ground to at least the mid-section of the structure? If so, is the portion lying within the plot boundary ≥2 m in length?
NO
Structure is not sampled
YES
YES
YES
Is live foliage present?
Is at least 75% of the length of the structure lying on or above the surface (i.e., not partially or wholly rotted into the ground)?
NO
Structure is not sampled
NO
YES
Live tree
Snag
Downed wood

Figure 10. *Key used to categorize post-fire forest stand structure as live trees, snags, and downed wood in field plots.*

within the plot. Calipers were used to measure the diameter of downed wood at the centre of the portion lying within the plot. Downed status, description, and decay were also recorded (details provided in secondary observations section below). Yellow tree marking paint was applied along the length of all downed wood to indicate it had been measured. The final step was to tally and record data on additional downed wood in the plot in the same way.

Monitoring temporal changes in residual structure

To determine short-term changes in post-fire residual structure, all 50 field plots were revisited in 2006 and 2007 (i.e., in the second and third year after fire) to document survival of trees and fall rates of trees and snags. In each plot, stems painted (and tagged) as live trees or snags in 2005 were located systematically using the numbered tags and their location on the HRP base photo and their current status recorded. Five categories were used to describe live tree status (0, no change; 1, dead, standing; 2, fallen, dead; 3, fallen, live; 4, broken; 23 was used for fallen stems where live/dead status not recorded). Three categories were used to describe snag status (1, no change; 2, fallen; 4, broken). If fallen, trees and snags were marked with a line (>1 m) using the appropriate marking paint (e.g., pink for live trees, blue for snags) along the bole so that they could be readily identified as previously fallen structure in subsequent years.

Data collected for assessing photo interpretation error

Data from the 50 field plots was also used to understand the accuracy of the photo interpretation and determine correction factors. Errors associated

with interpreting residual structure from HRP photos include detection and classification and can be either omission errors (underestimation) or commission errors (overestimation).

Data collected to determine detection errors included the location of all residual structure in the field plots (as geo-referenced points). Structure that was correctly detected by the photo interpreter could be assessed for classification accuracy using field measured attributes (i.e., structure class, species, and diameter).

Secondary data and observations

Field plots allow the gathering of information beyond the primary data (which in this case was tree, snag, and DWD measurements). Such measurements may become important in post-hoc analyses, as well as for standardizing and comparing results among related studies. Thus, the additional data collected in the 50 field plots and methods used to collect it are outlined below.

Site data

In each plot, percent slope was recorded from the high point along the plot perimeter across the plot centre to the low point along the opposing plot

Table 7. *Residual stand structure attribute data collected in field plots.*

Structure and variable	Note
Trees	**Minimum 2 m height**
Species	Tree species only
Diameter at breast height (dbh)	To nearest 0.1 cm
Crown scorch	Visual index describing the loss of green foliage at the time of fire (0%, 10%, 25%, 50%, 75%, 90%)
Stem breakage	Percent of bole broken off is estimated (e.g., a tree has a broken top estimated to be 25% of entire tree bole thus stem breakage = 25%)
Snags	**Minimum 2 m height**
Species	Tree species only
Dbh	To nearest 0.1 cm
Origin	Pre- or post-fire
Stem breakage	As for trees
Decay	Classification modified from Cline et al. (1980) and Raphael and Morrison (1987) (see Figure 16)
Downed wood	**At least 75% of the length must be clearly lying on or above the ground surface; minimum 2 m length**
Species	If species could not be determined then classified as conifer or hardwood
Length	Length to 0.1 m
Diameter	Diameter to 1.0 cm; measurement taken at centre of portion lying within the sample plot perimeter
Origin	Pre- or post-fire
Classification and decay	See Figure 19

perimeter using a vertex unit. Slope conditions were generalized by avoiding small mounds and depressions, if present. The aspect (down slope azimuth) was recorded using a compass along the line of sight of the slope measurement. The pre-fire forest cover for the plot and immediately surrounding stand was visually estimated (based on relative canopy cover) for overstory trees (e.g., 60% black spruce, 30% jack pine, 9% aspen, 1% paper birch) and understory trees and shrubs (e.g., 15% alder, 20% black spruce regeneration). The slope position(s) of the plot relative to the surrounding stand (crest, upper, middle, lower, toe, flat) was also recorded. Additionally, stand age and site class were extracted from the Ontario Forest Resource Inventory database (OMNR 2000). Soil moisture information (dry, mesic/moist, wet) was extracted from a soil moisture database (Agriculture and Agri-Food Canada 1996, OMNR 1977), corrected using a topographic wetness index (Wolock and McCabe 1995). Site data for the 50 field plots are provided in Table 8.

Fire damage – forest floor fire severity

To assess fire damage to the forest floor, in each plot a 24 m transect was established outwards 12 m east and west from the plot centre using a 30 m tape. The outermost points were permanently marked with a flagged pin. Photos of the eastern and western 12-m-long segments were taken from plot centre outwards with the centre stake clearly visible (e.g., Figure 11). Starting from the centre stake and going east and west towards the edge of the plot, using a small hole at each 1 m point, the depth and relative composition of the litter (e.g., jack pine/black spruce needles) and depth of burned duff or moss and depth of unburned duff above mineral soil or rock were recorded (Figures 12, 13) (25 points in total). If no litter or duff was present at a sample point, it was recorded as exposed mineral soil, rock, log (lying flat on the ground), or stump/root as appropriate. Depth of unburned moss to 40 cm or to the water table was recorded. Mineral soil was recorded up to a depth of 10 cm. The presence of mineral soil with cobble-sized stones was recorded as mineral soil/rock. Points were not sampled if a tree or snag had uprooted since fire had occurred causing post-fire forest floor disturbance.

Fire damage – tree crown scorch

Tree crown scorch, a measure of fire severity, was visually estimated using field observations (combined with base photo for reference) and documented as the percent loss (relative volume) of green foliage at the time of photo capture. Categories used to describe relative foliage loss were: 0, 10, 25, 50, 75, and 90% (Figure 14).

Snag origin and decay

Snag origin was separated into snags present before the fire (i.e., pre-fire snag) and those resulting from the fire (post-fire or fire-created snag) (Figure 15). A pre-fire snag generally had loose bark, rapid post-fire loss of bark, or burn out its base. Branches, if present, would often have remnants of arboreal lichens. Coarse branches or branch stubs were often present with few, if any, fine twigs. In contrast, a fire-created snag generally had brown foliage (surface fire) or few to many fine twigs (crown fire) with no burn out at the base and minimal bark loss soon after fire (Figure 16). The following 5 decay classes were used to describe snags (Figure 16, modified from Cline et al. 1980, Raphael and Morrison 1987): (1) brown foliage present, (2) fine twigs present (few or many), (3) coarse branches present (few or many), (4) branch stubs present (few or many), and (5) no branch stubs present/burnout, bark loss on structure, most notably at the base of the bole (Figures 17-18). The percent of bole remaining was also estimated. For example, a black spruce snag with a broken top estimated to be 25% of the entire snag, stem breakage would equal 25% (or 75% of snag remains).

Table 8. *Site data for 50 field plots.*

Fire ID	Field Plot ID	HRP plot ID[a]	Latitude (NAD 83)	Longitude (NAD 83)	Forest cover[b]	Stand age[c]	Slope (%)	Aspect	Site class[d]	Moisture[e]
FOR-14	4	L047-117	48.296173	-91.641111	Sb, Bw, Pr, Pj	No data	21	270	No data	dry
	5	L049-121	48.292688	-91.664225	Pw, Bw, Po, Sb	No data	36	225	No data	dry
	9	L050-125	48.293326	-91.646809	Sb, Pj, Po, Bw	No data	18	10	No data	dry
	10	L050-126	48.293377	-91.642657	Sb, Pj, Pr, Po	No data	8	200	No data	dry
	15	L051-129	48.290294	-91.644153	Sb, Po, Bw, Pw, Pr	No data	19	306	No data	dry
	16	L051-128	48.290448	-91.638626	Pw, Po, Ms, Pr, Bw, Sb	No data	26	155	No data	dry
	17	L053-133	48.290294	-91.644153	Pj, Bw, Sb, Po, Pw	No data	32	260	No data	dry
	18	L053-134	48.287379	-91.658707	Po, Sb, Bw, Pj	No data	50	61	No data	dry
	21	L054-137	48.287775	-91.642350	Po, Sb, Pw, Pr, Pj	No data	8	159	No data	dry
	23	L056-144	48.284291	-91.662751	Sb, Pj, Bw, Pw	No data	1	180	No data	dry
	24	L056-143	48.284397	-91.658631	Pj, Sb, Bw, Po, Bf	No data	10	118	No data	dry
	34	L057-145	48.281056	-91.664545	Sb, Pj, Bw	No data	7	340	No data	dry
THU-30	1	L077-194	50.581109	-88.753063	Sb, Bf, Bw, Po	65	8	220	1	dry
	6	L078-197	50.575960	-88.741339	Sb, Pj, Po	65	12	259	3	dry
	7	L080-204	50.572535	-88.746020	Pj, Sb	60	1	360	3	dry
	8	L080-203	50.572614	-88.740240	Sb, Pj	65	4	220	3	dry
	11	L082-208	50.567404	-88.726512	Sb, Pj	60	17	270	1	dry
	14	L078-198	50.576042	-88.735688	Sb, Pj	65	3	95	3	dry
	20	L075-189	50.578886	-88.722572	Sb, Bw	95	10	45	3	dry
	25	L073-185	50.584300	-88.713799	No data	70	No data	No data	2	dry
	27	L072-182	50.586968	-88.719634	Sb, Pj	70	0	n/a[f]	1	wet
	28	L072-181	50.586997	-88.715286	Sb	95	0	0	1	wet

THU-31	8	L087-221	50.285000	-88.777378	Sb, Pj	81	4	351	1	dry
	9	L087-220	50.285163	-88.773194	Sb, Pj, Po, Bw	106	1	180	1	dry
	14	L088-222	50.282799	-88.781885	Sb, Pj	76	6	191	1	dry
	16	L088-224	50.282862	-88.772983	Po, Pj, Sb, Bw	76	10	325	3	dry
	17	L088-225	50.282912	-88.768528	Po, Pj, Bw, Sb, Bf	106	14	346	1	dry
	18	L089-226	50.283029	-88.764000	Pj, Sb	83	13	340	1	dry
	19	L089-227	50.282961	-88.759707	Sb	146	0	n/a	3	wet
	22	L093-237	50.279835	-88.781080	Sb, Pj, Bw, Po	81	9	356	1	dry
	24	L093-235	50.279905	-88.772279	Pj, Sb, Po	81	19	250	1	dry
	31	L094-239	50.277486	-88.777016	Po, Pj, Sb	76	7	294	1	dry
	32	L094-240	50.277544	-88.772507	Sb, Po, Pj, Bf	81	1	344	2	dry
	38	L098-253	50.274825	-88.783297	Sb, Sw, Bw, Po	76	10	120	1	dry
	39	L098-252	50.274777	-88.778936	Sb, Pj	76	5	352	1	dry
	48	L099-256	50.272256	-88.772939	Sb, La	76	0	n/a	3	wet
THU-67	4	L132-379	50.174538	-89.697999	Sb, Pj	150	5	88	2	mesic
	8	L143-410	50.176947	-89.711838	Sb, Pj	155	0	n/a	1	wet
	9	L143-411	50.176904	-89.707617	Sb, Pj	150	6	220	3	wet
	10	L143-412	50.177082	-89.702441	Sb, Pj	145	2	15	2	wet
	15	L142-407	50.179268	-89.725528	Sb, Bw, Pj, Po	135	5	178	1	mesic
	16	L142-406	50.180169	-89.719257	Sb, Pj, Bw	165	7	172	1	wet
	17	L142-405	50.179539	-89.715555	Sb, Pj	105	9	4	2	mesic
	38	L139-397	50.181831	-89.721874	Sb, Pj	115	11	200	1	wet
	44	L138-391	50.184999	-89.701025	Sb, Pj, Bw	160	29	160	1	dry
	63	L137-390	50.187394	-89.702017	Sb, Pj, Bw	155	9	170	1	wet
	64	L137-389	50.187186	-89.706128	Sb, Pj, Bw	80	5	90	1	mesic
	69	L134-384	50.189516	-89.704727	Sb, Pj, Po, Bw	155	11	35	1	dry
	70	L134_383	50.189703	-89.700530	Sb, Pj, Po	155	1	90	1	dry
	89	L117-324	50.191819	-89.700185	Sb, Pj, Bw	No data	8	174	2	dry

[a] The HRP plot ID number contains the flight line number (e.g., L137) and photo capture number (e.g., 390).
[b] Forest cover refers to overstory trees ranked by importance (relative canopy cover) within and surrounding the sample plot area as observed in the field. See Appendix IV for species codes.
[c] Stand age is from the Ontario Forest Resource Inventory database (OMNR 2000), corrected to 2006.
[d] Site class is from Ontario Forest Resource Inventory database (OMNR 2000); where 1=high growth rate, 2= medium growth rate, 3=low growth rate, and 4=extremely slow growth rate.
[e] Generalized soil moisture (dry, mesic/moist, or wet) was extracted from a moisture database (Agriculture and Agri-Food Canada 1996, OMNR 1977) and corrected using a topographic wetness index (Wolock and McCabe 1995).
[f] n/a - not applicable

Figure 11. *East (a) and (b) west 12 m forest floor fire severity transects across a residual structure sample plot.*

Figure 12. *Sampling at a forest floor fire severity transect point (a) showing <1 cm of burned duff on mineral soil (b).*

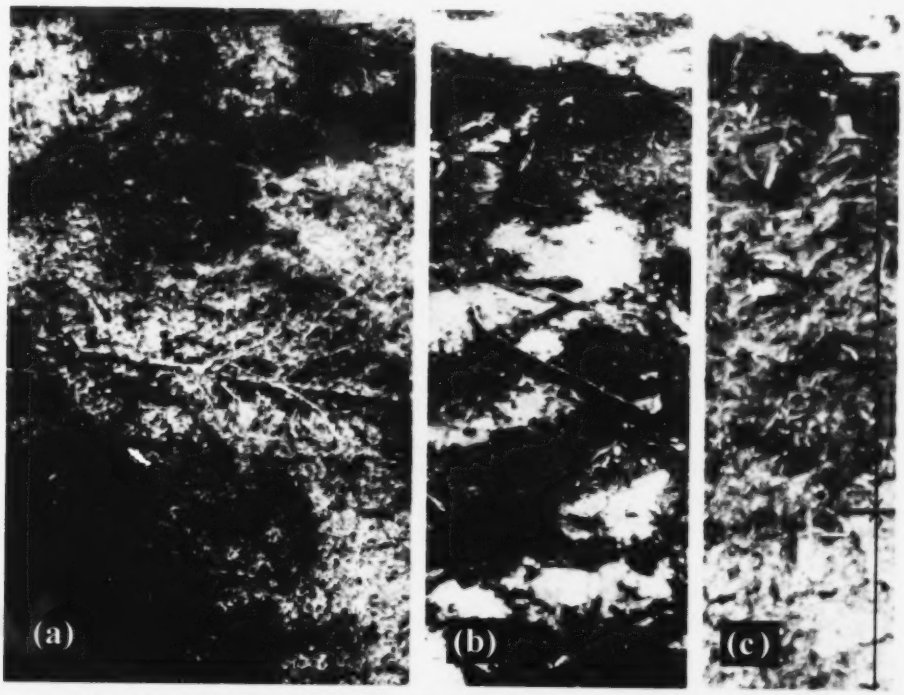

Figure 13. *Examples of (a) scorched and unburned moss, (b) rock substrate with <1 cm of burned duff on the surface, and (c) a soil pit showing 2 cm of burned duff on 8 cm of unburned duff on mineral soil.*

Figure 14. *Examples of tree crown scorch categories: (a) 10% on black spruce (b) 25% on paper birch (c) 25% on black spruce, and (d) 90% on paper birch, and*

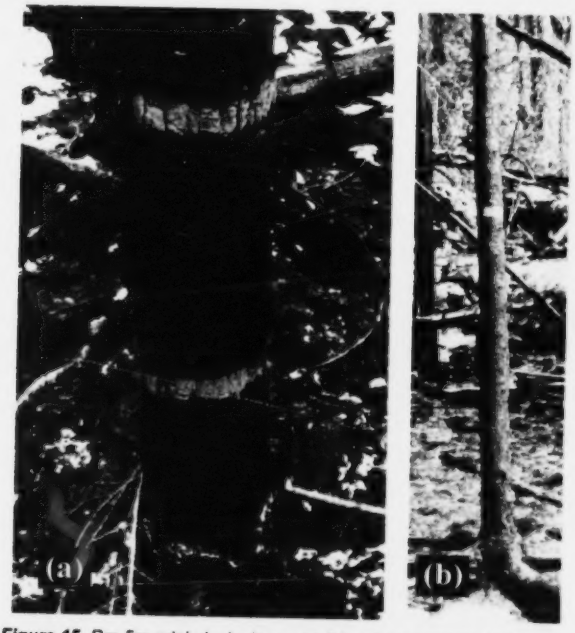

Figure 15. *Pre-fire origin jack pine snag (a) and a fire-origin black spruce snag (b). Note the lack of bark and burnout at the base of the pre-fire snag.*

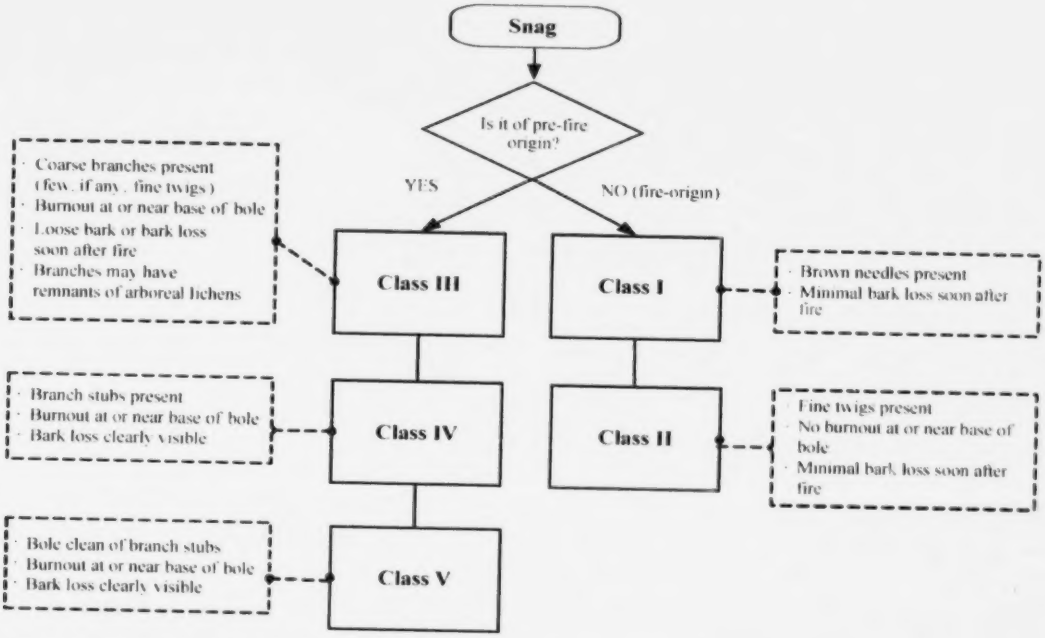
Snag
Is it of pre-fire origin?
YES
NO (fire-origin)
· Coarse branches present (few, if any, fine twigs)
· Burnout at or near base of bole
· Loose bark or bark loss soon after fire
· Branches may have remnants of arboreal lichens
Class III
Class I
· Brown needles present
· Minimal bark loss soon after fire
· Branch stubs present
· Burnout at or near base of bole
· Bark loss clearly visible
Class IV
Class II
· Fine twigs present
· No burnout at or near base of bole
· Minimal bark loss soon after fire
· Bole clean of branch stubs
· Burnout at or near base of bole
· Bark loss clearly visible
Class V

Figure 16. *Field classification of snag decay (modified from Cline et al. 1980, Raphael and Morrison 1987).*

Figure 17. *Sample pre-fire origin snags classified as decay class III (a, jack pine) and V (b, unknown sp.).*

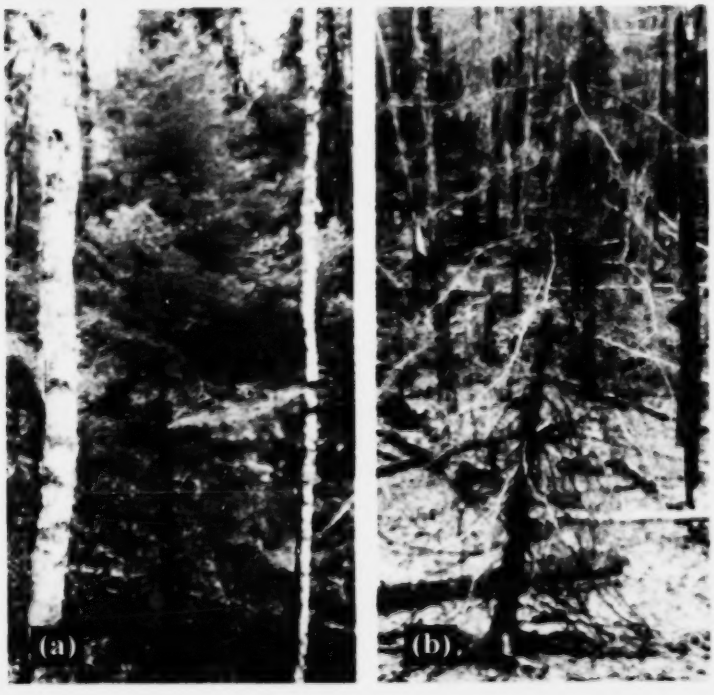

Figure 18. *Example fire-created snags classified as decay classes I (a, balsam fir) and II (b, black spruce).*

Downed wood origin and decay

Although definitions for downed wood decay stages are available (e.g., Maser et al. 1979, Sollins 1982, Bartels et al. 1985), the unique timing of the downed wood assessment following fire warranted a more detailed description resulting in the following descriptive classification categories (Figure 19). Downed wood status separated that present prior to fire (e.g., pre-fire – was on the ground during the fire) from that created by the fire. Other data collected included downed wood species and orientation (angle of downed wood estimated in degrees). General decay of each piece of downed wood was described as (1) hard, (2) partially decayed, or (3) heavily decayed (i.e., soft) (Figures 20-21). Bole condition was described based on the presence of (1) green leaves, (2) fine twigs, (3) coarse branches or stubs or (4) none and the percentage of bark visible (visible surface) in 1 of 6 classes (0, 1 – 24, 25 – 49, 50 – 74, 75 – 99, 100%). The relative condition of the downed wood was described as (1) not burned, (2) moderate - light char, (3) heavy char, moderate-light burn, or (4) heavily burned (Figure 22).

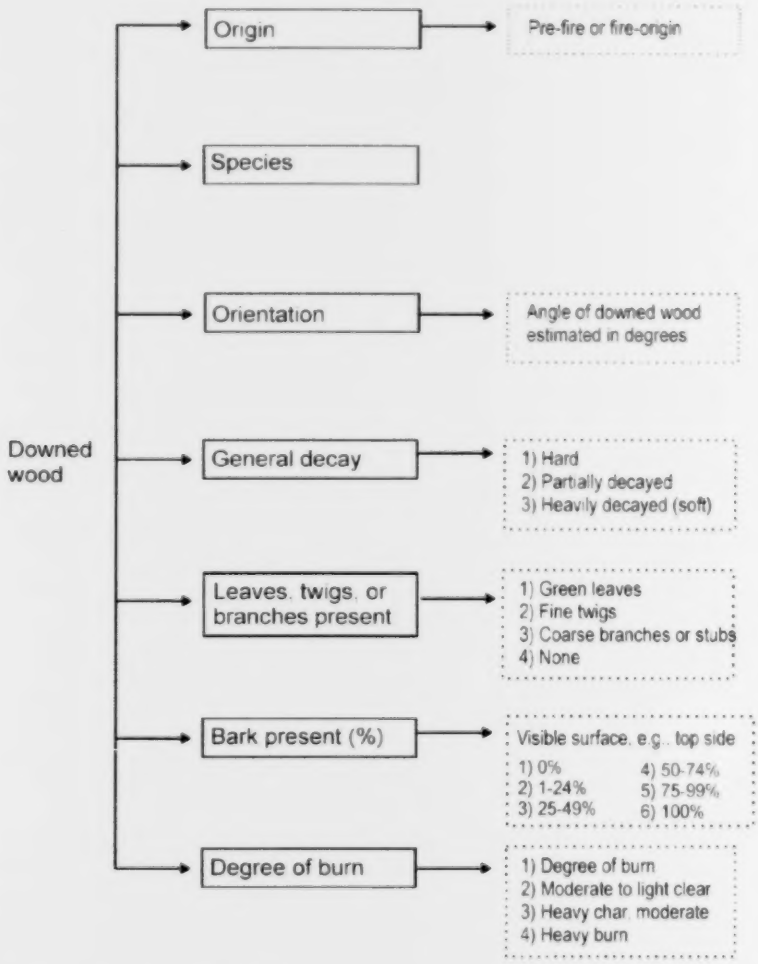

***Figure 19**. Classification of downed wood in the field.*

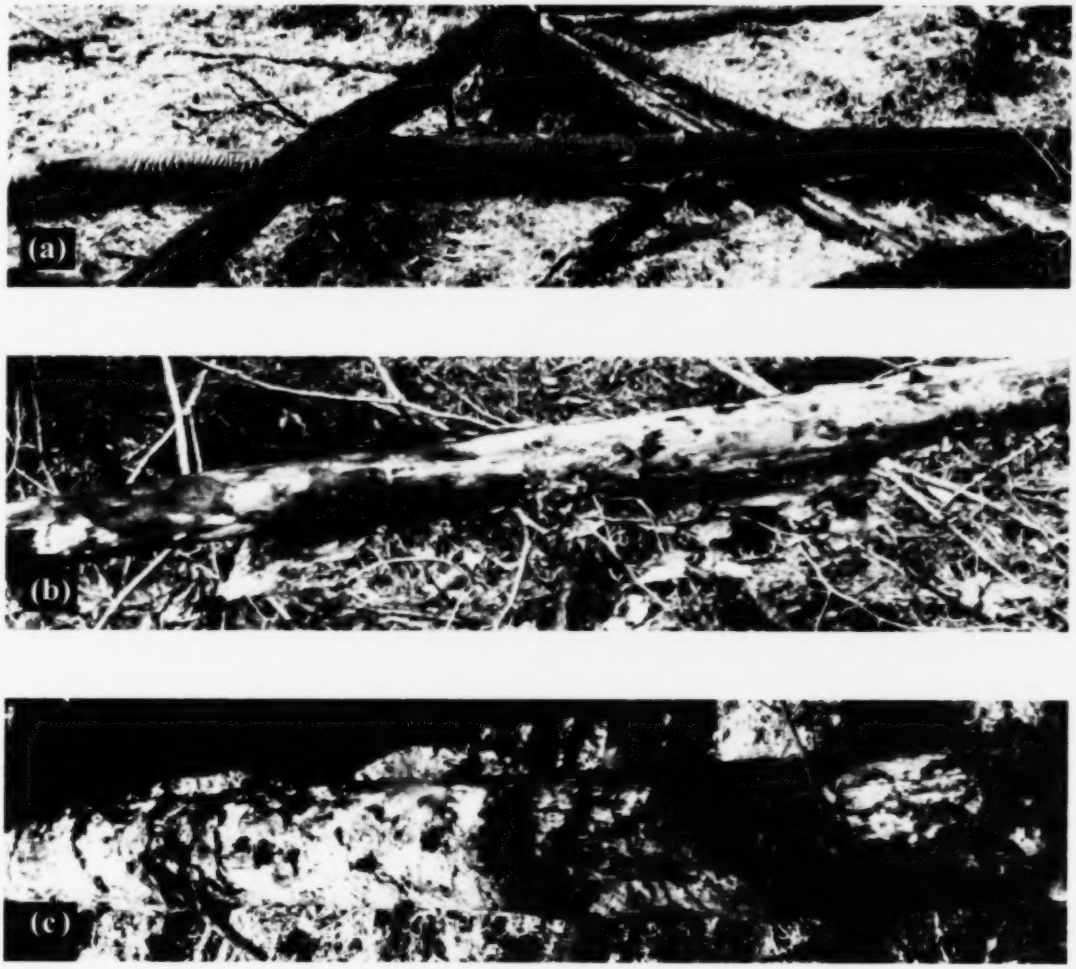

***Figure 20**. Representative examples of downed wood showing hard wood (a, b) and partial decay (c).*

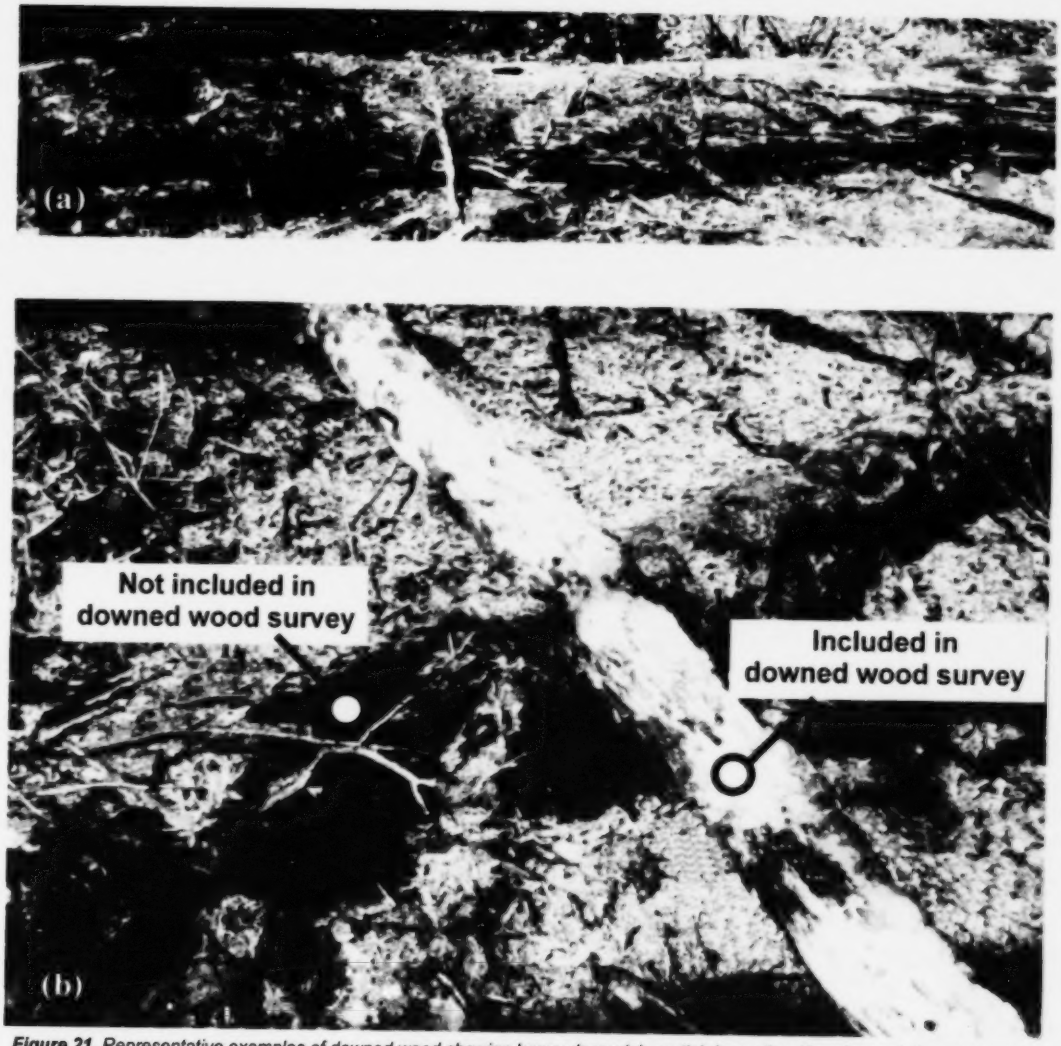

Figure 21. *Representative examples of downed wood showing heavy decay (a), partial decay (b; with yellow paint), and downed wood that was not included in sample (b).*

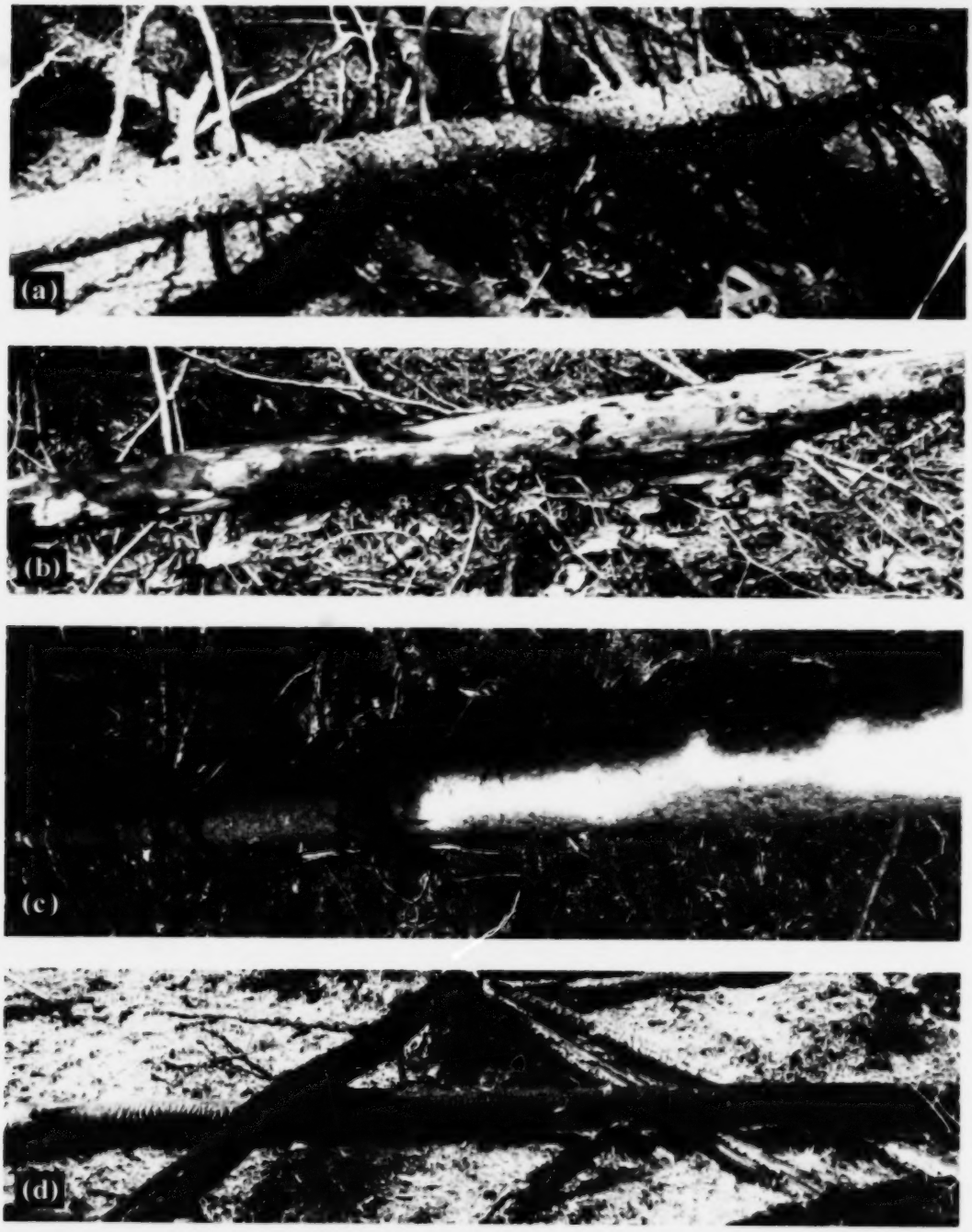

Figure 22. *Representative examples of downed wood that is (a) not burned, (b) lightly charred (c) moderate-lightly burned, and (d) heavily burned.*

HRP vs. field sampling cost and feasibility comparison

Many factors influence the feasibility of using HRP for field sampling, one of which is its cost compared to traditional field sampling. Below I outline approximate sampling costs for comparative purposes.

Approximate cost of collecting comparable data on post-fire residual structure was $130 per plot for HRP vs. $1,012 per plot for field sampling (Table 9). For HRP data collection, one half (50.7%) of the costs were for photo capture including helicopter ferry time. Nearly one third of the field sampling cost (32.7%) was for labour and another third (30.8%) were operational costs (meals, lodging, vehicle rental, and fuel). Combining the cost of HRP (660 plots), field sampling (a subset of 50 plots), and error assessment (i.e., entity matching), the cost per plot was $217. A subsequent report will document error rates associated with the use of HRP to sample residual structure.

Field sampling alone was very costly but was critical to assess photo-interpreter error and thus must be incorporated in an HRP sampling design and factored in as part of the cost. Field sampling also allowed the collection of data that could not be measured through photo-interpretation, which in addition to being useful in assessing photo-interpreter error, can provide additional information not available from use of photos alone. For example, discerning pre-fire from fire-created snags or downed wood.

As previously reported (Rhody 1977, Hall 1984, Spencer and Hall 1988, Hall et al. 2001), on a per plot basis, field sampling was more expensive than HRP due to the time and personnel required. The cost of collecting field data increases if extensive sampling effort is required and when sample points are geographically dispersed or remote (Dendron Resource Surveys 1981) often making HRP sampling relatively less expensive (Kirby 1980). Although the cost of using HRP is influenced by aircraft cost and availability, accessibility, and distance among sampling locations, the overall cost per plot decreases as the area surveyed and number of HRP plots captured per area increases (Dendron Resource Surveys 1981, 1988; Hall and Aldred 1992). Although actual costs in this work differed from those reported in other studies, sampling using HRP was almost always cheaper on a per plot basis. For example, Dendron Resource Surveys (1988) reported approximate costs of using HRP and field methods to sample 1,000 plots (species, height, and crown dimensions of trees) at $53 and $102 per plot, respectively. Dendron Resource Surveys (1997) reported HRP costs of $100 per plot versus $150 or more for timber cruises and $1,000 per plot if helicopters were used to transport field crews. However, small sample sizes may not warrant the use of HRP. For example, McCleary (2005) reported that field sampling costs were 40% of HRP costs when data on trees, snags, and downed wood were collected on <20 plots.

The use of HRP not only allowed 660 plots to be sampled within a short timeframe among 11 fires at a reasonable cost but also allowed an unbiased distribution of plots, which is often not realized with field sampling. This is reflected in the high sampling intensity in this study (~60 plots per 1,000 ha of fire area) compared with field studies (~0.1 – 11 plots per 1,000 ha of fire) as reported in the literature.

Table 9. *Approximate project costs for use of high resolution photo (HRP) plots and field plots to sample post-fire residual structure in boreal Ontario.*

Activity		HRP (660 plots)[a]		Field (50 plots)[b]	
		Hours	Cost ($)	Hours	Cost ($)
Project planning	Contract development and liaison	120.0	3,120	0	0
	Plot selection (23$/hr)	120.0	2,760	40.0	920
	Field work preparation (23$/hr)	0	0	240.0	5,520
	Field equipment	0	0	n/a	8,300
	Total	240.0	5,880	280.0	14,740
Photo acquisition	Helicopter ferry	10.1	15,200	0	0
	Aerial photo capture (739 plots)[a]	17.1	28,170	0	0
	Total	27.2	43,370	0	0
Photo interpretation	Photo-developing ($10/ pair, 6 inch prints)	0	7,910	0	0
	Photo-pair selection 23$/hr	40.0	920	0	0
	Photo-interpretation (660 plots; $40/plot)	0	26,400	0	0
	Data checking	40.0	1,050	0	0
	Total	80.0	36,280	0	0
Field sampling	Meals, lodging and vehicle rental/fuel	0	0	0	15,600
	Data collection[c] (50 plots) ($23/hr)	0	0	720.0	16,560
	Data entry and checking ($23/hr)	0	0	160.0	3,680
	Total	0	0	880.0	35,840
Error assessment (entity matching 50 plots @$23/hr)		**320**	**7,360**	--	--
Total (not including error assessment)		**347.2**	**85,530**	**1,160.0**	**50,580**
Total per plot (not including error assessment)		**0.5**	**130**	**24.0**	**1,012**
Total per plot (HRP + field + error assessment)		--	**217**	--	--

[a] 660 of 739 photo plots were interpreted
[b] Tree and snag data were collected in 50 field plots; downed wood data were collected in a subset of 30 of those plots
[c] Field data collection included establishing plot (1 hour), sampling a forest floor fire severity transect (1 hour), and mapping and measuring trees, snags (4 hours), and downed wood (2 hours)

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Appendices

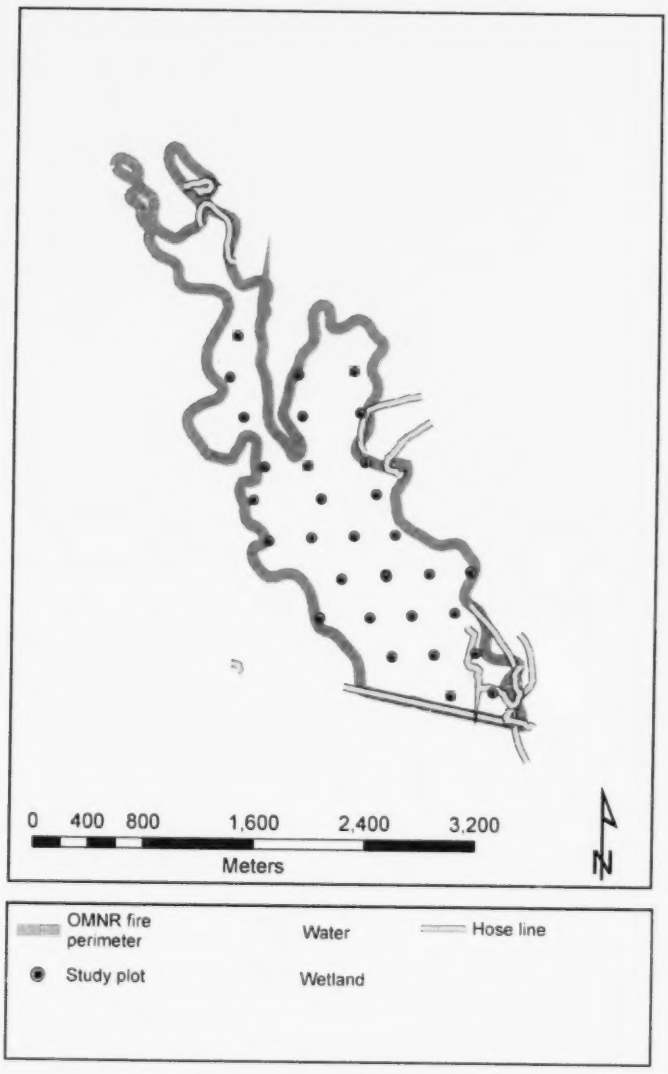
APPENDIX I. Forest unit descriptions for Quetico Park sample plots

Since forest resource inventory data was not available for Quetico Park sample fires (FOR-14 and FOR-24), the forest unit classification system developed for the park was used. (Source: Quetico Forest Inventory 2000; http://ims.legacyforest.ca/main/; accessed September, 2006)

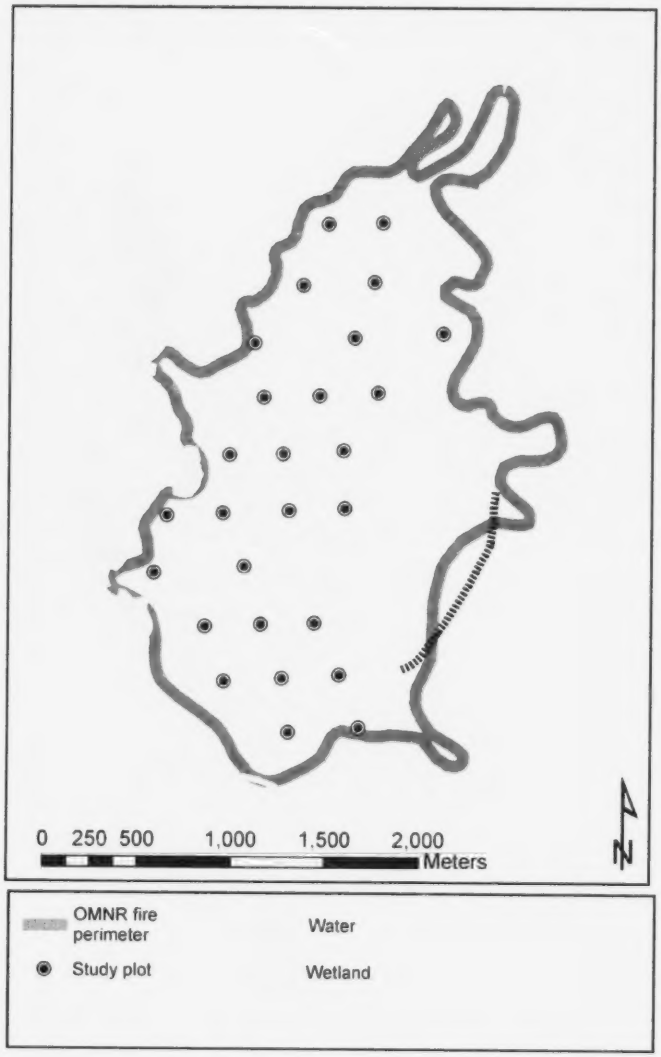
Forest unit	Description	Sort Rule
Alder	Alder	
Bf	Balsam Fir	Bf >=0.4 AND conifer >=0.5
Bw	White Birch	Bw >=0.6 AND Po+Bw >=0.7
Gully	Gully	n/a
HwdDom	Hardwood Dominant	Hardwood >=0.7
HwdMix	Hardwood Mixedwood	Hardwood mixedwood >=0.5
MC1	Conifer Dominated Mixedwood 1	Sb+Sw+Pj+Pr+Bf >=0.7 AND Bf <=0.1 AND Po+Bw <=0.2
MC2	Conifer Dominated Mixedwood 2	Conifer >=0.7
OC	Other Conifer	Ce+La >=0.5
OH	Other Hardwood	Other hardwood >=0.3
Pj	Jack Pine	Pj >=0.7
Po	Poplar	Po >=0.7
Pwr	Red / White Pine	Pw+Pr >=0.4
Rock	Rock	n/a
SPL	Black Spruce (Lowland)	Sb+Ce+La >=1 in lowland condition
SPU	Black Spruce (Upland)	Sb >=0.7 in upland condition
Swamp Muskeg	Swamp / Muskeg	n/a
Water / No Data	Water / No Data	n/a

APPENDIX II. Maps of sample fires

Cochrane 10



Timmins 5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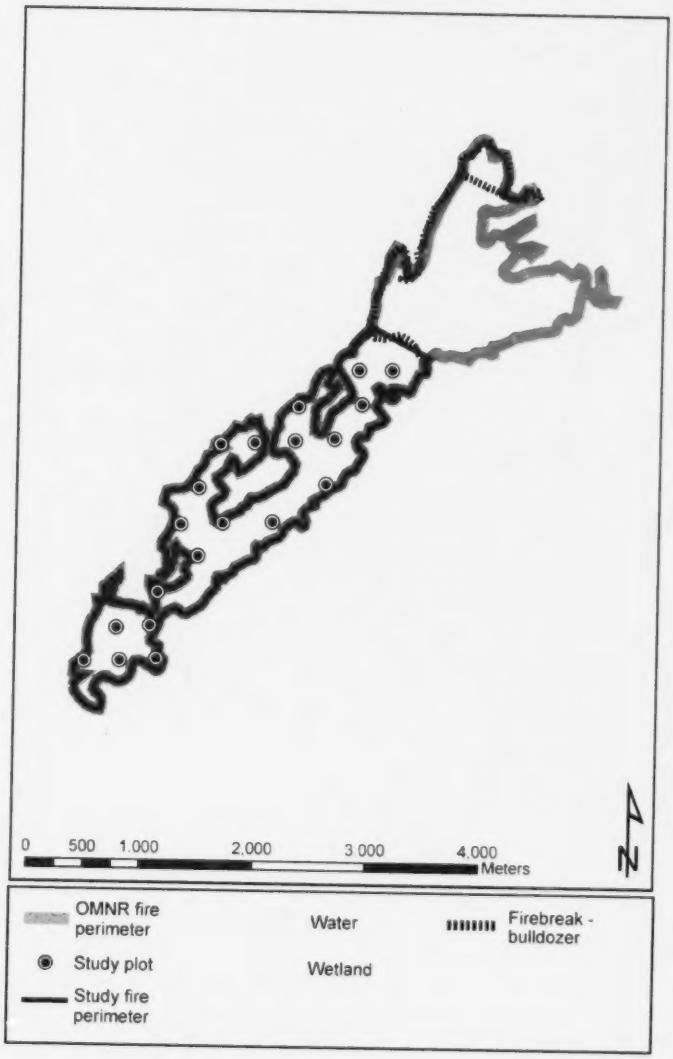
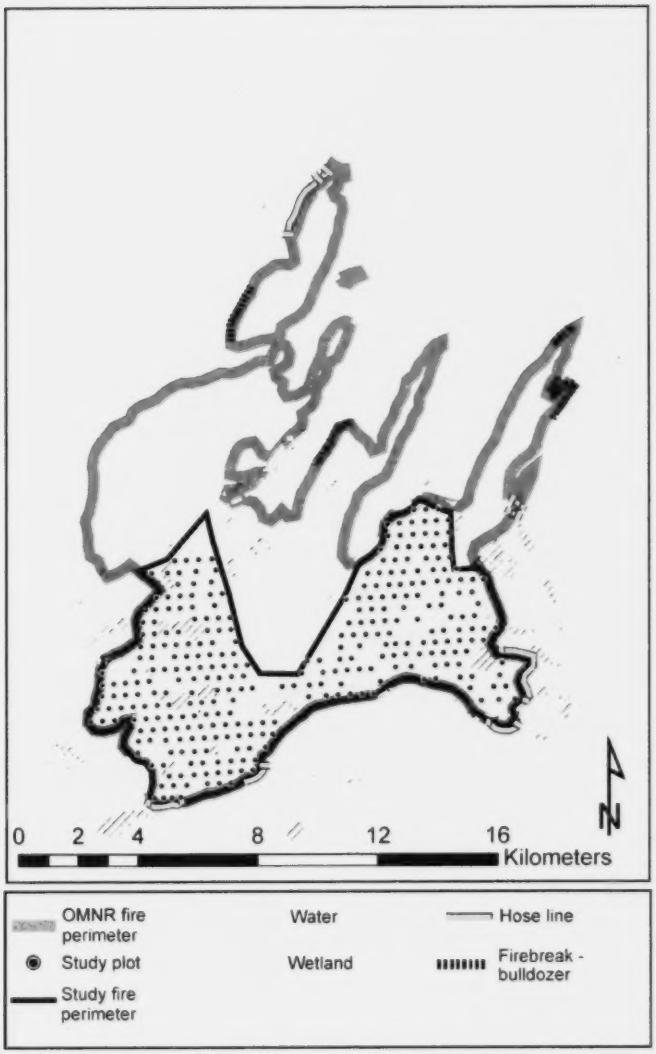
Meters
N
OMNR fire perimeter
Study plot
Water
Wetland

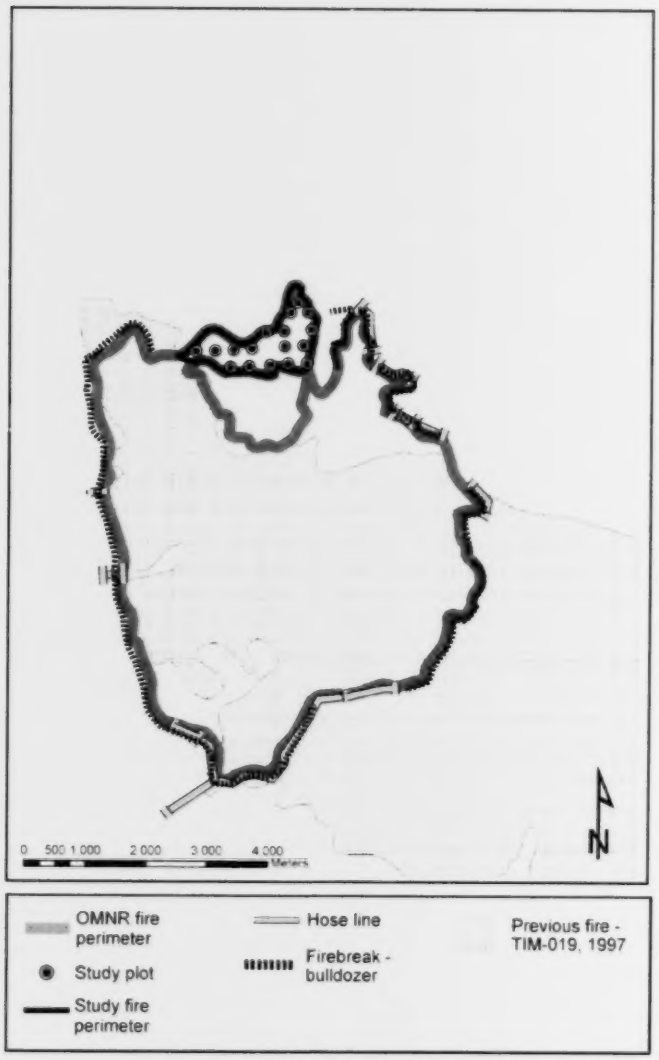
Timmins 7


0 500 1,000 2,000 3,000 4,000
Meters
N
OMNR fire perimeter
Study plot
Study fire perimeter
Water
Wetland
Firebreak - bulldozer

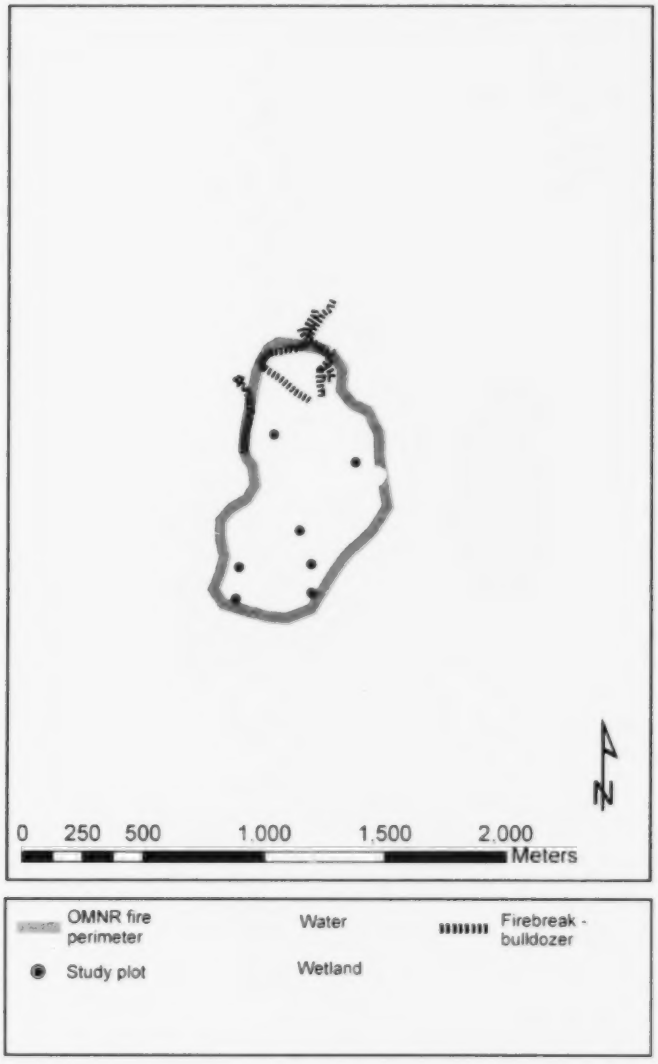
Nipigon 20


0 2 4 8 12 16
Kilometers
N
OMNR fire perimeter
Study plot
Study fire perimeter
Water
Wetland
Hose line
Firebreak - bulldozer

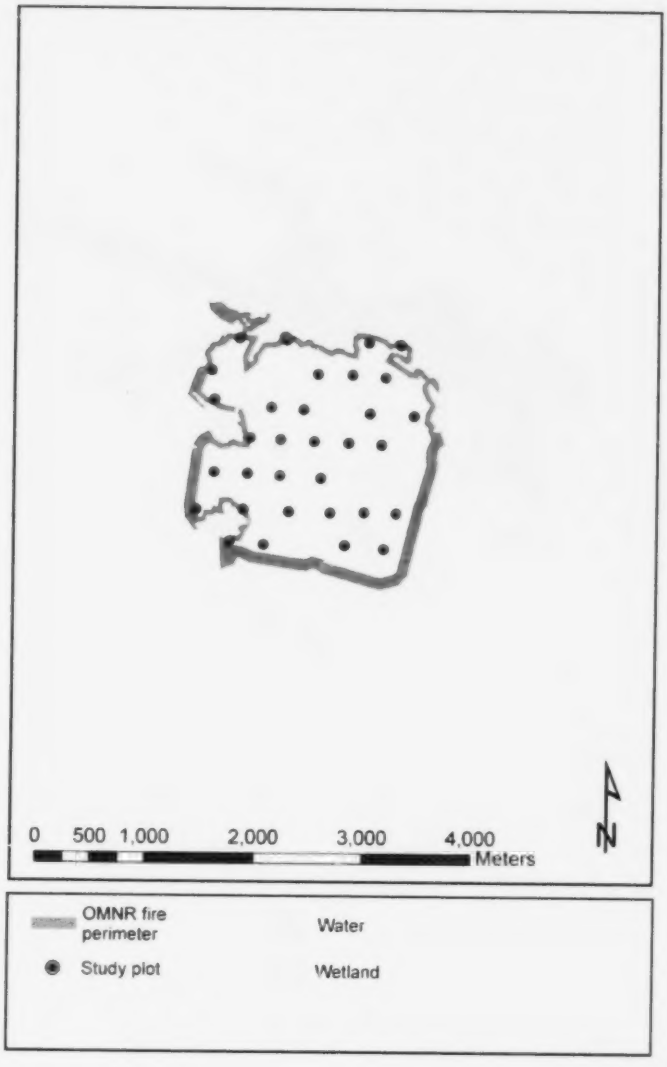
Timmins 19


0 500 1 000 2 000 3 000 4 000
Meters
N
OMNR fire perimeter
Study plot
Study fire perimeter
Hose line
Firebreak - bulldozer
Previous fire - TIM-019, 1997

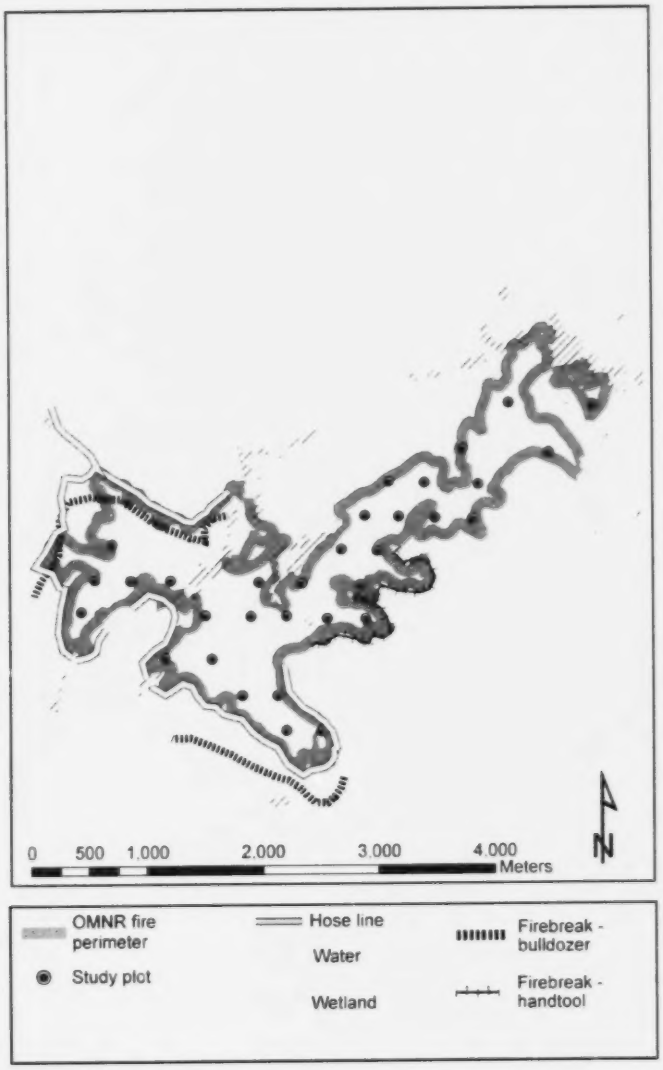
Chapleau 18


0 250 500 1,000 1,500 2,000
Meters
OMNR fire perimeter
Study plot
Water
Wetland
Firebreak - bulldozer

Fort Frances 14



Thunder Bay 30



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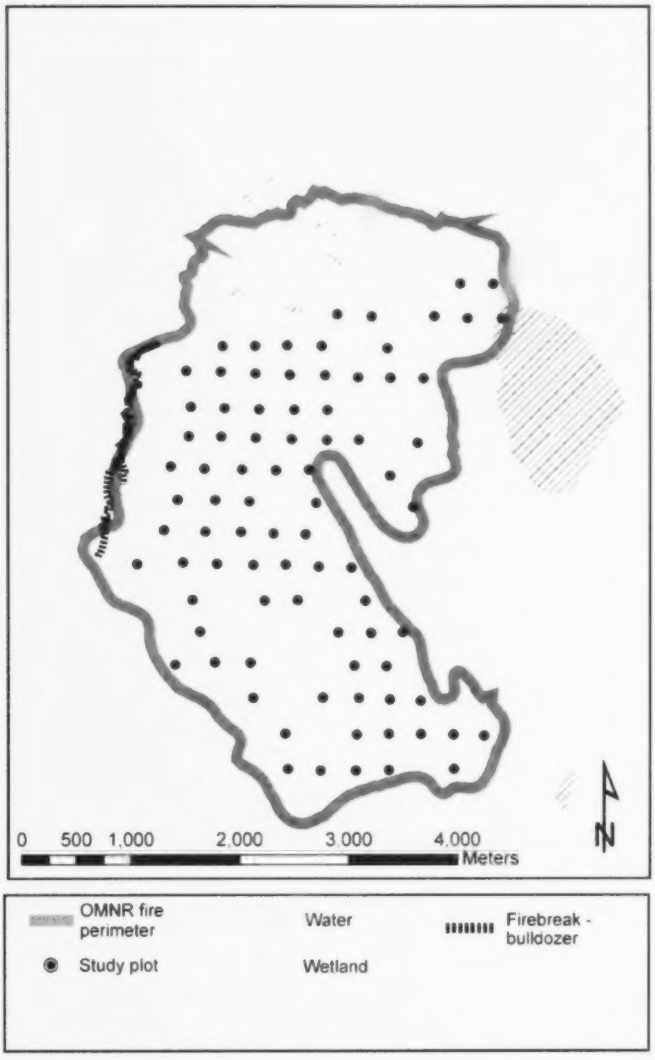
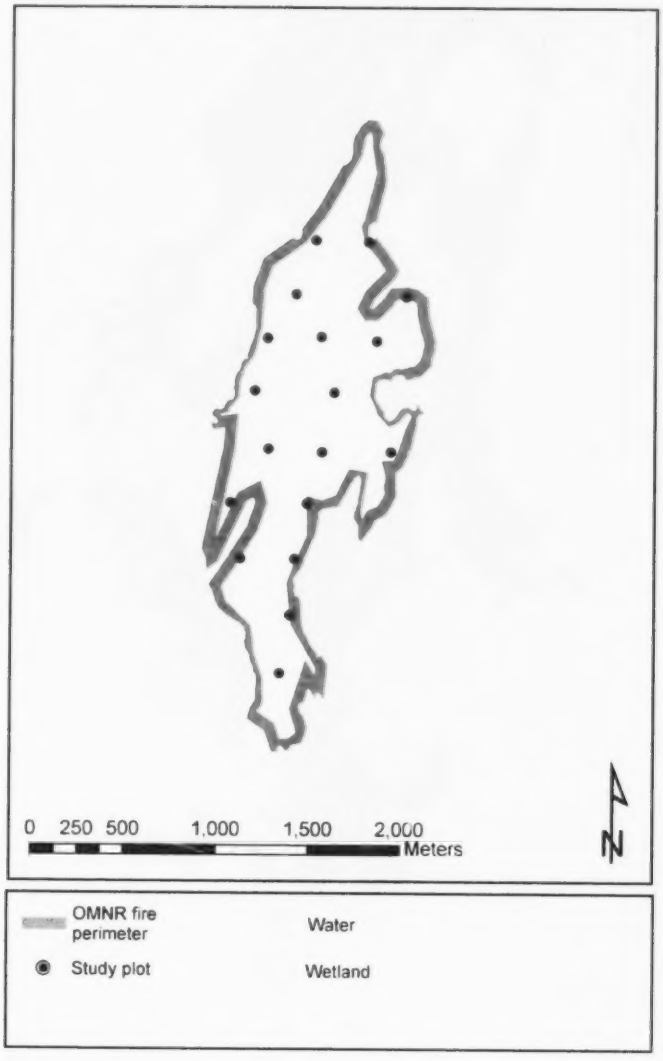
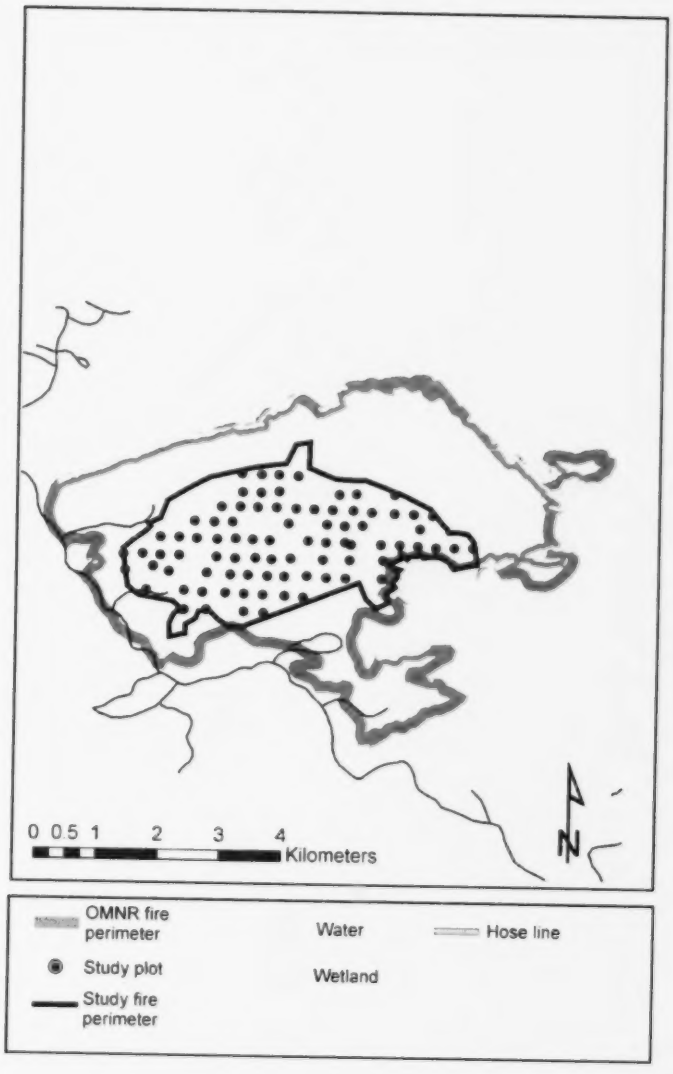


Fort Frances 24



Thunder Bay 67



APPENDIX III. Species codes used to identify post-fire forest stand structure for photo interpreted and field plots.

Species code	Common Name	Scientific Name
Bf	Balsam fir	*Abies balsamea*
Bw	Paper birch, White birch	*Betula papyrifera*
By [a]	n/a	n/a
La	Larch, Tamarack	*Larix laricina*
Ma	Mountain ash	*Sorbus americana*
Ms	Red maple, Soft maple	*Acer rubrum*
Pj	Jack pine	*Pinus banksiana*
Po	Aspen, Balsam poplar, Big-toothed aspen	*Populus* sp.
Pr	Red pine	*Pinus resinosa*
Pw	Eastern white pine	*Pinus strobus*
S [a]	Spruce	*Picea* sp.
Sb	Black spruce	*Picea mariana*
Shb [a]	Shrub	n/a
Sl	Lowland spruce	*Picea mariana*
Su [a]	Upland spruce	*Picea mariana*
Sw	White spruce	*Picea glauca*
C1, C2, C3 [a]	Conifer snag in diameter class 1, 2, or 3	n/a
H1, H2, H3 [a]	Hardwood snag in diameter class 1, 2, or 3	n/a

[a] Codes used by photo-interpreter only. By (yellow birch) was recorded once by the photo-interpreter on all plots lacking live trees because the computer software (RIMAP©) would not accept plot data with only snags present. All instances of By were removed prior to analyses.

APPENDIX IV. Sample of raw data files generated by software program. RMAP©, following photo-interpretation of an HRP plot.

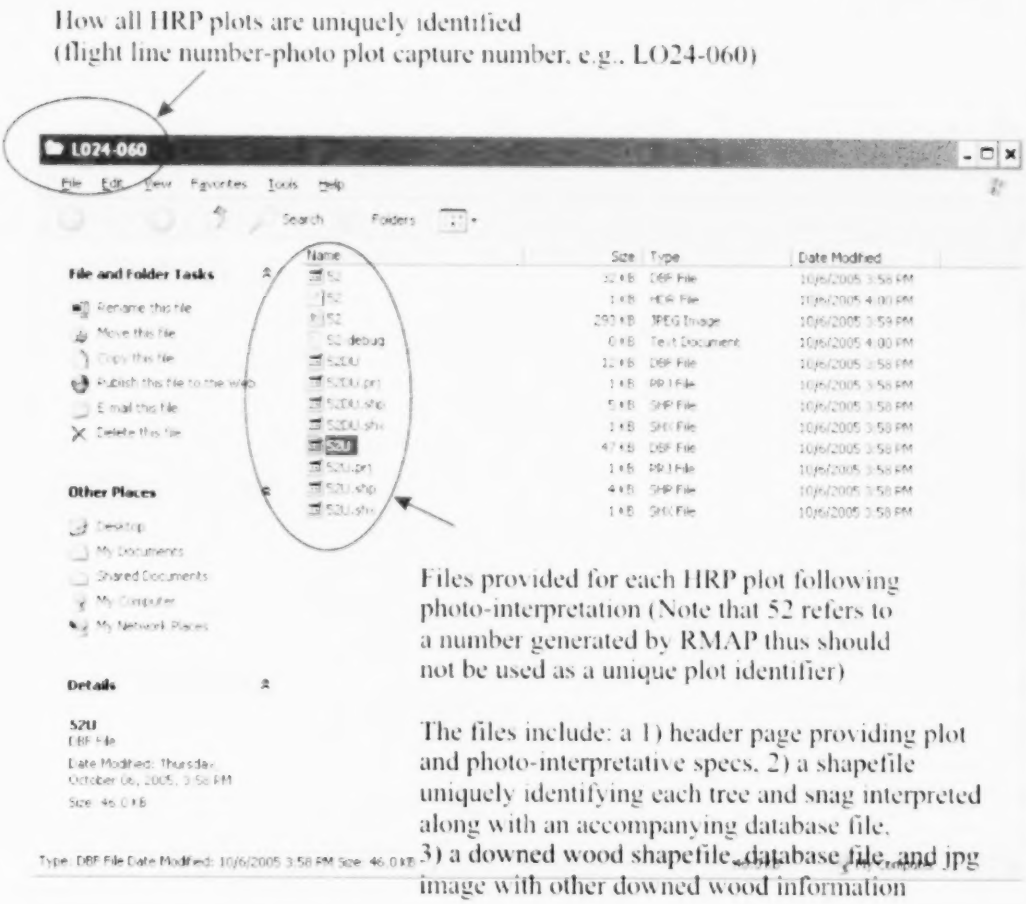

How all HRP plots are uniquely identified
(flight line number-photo plot capture number, e.g., LO24-060)
L024-060
File and Folder Tasks
Other Places
Details
Files provided for each HRP plot following photo-interpretation (Note that 52 refers to a number generated by RMAP thus should not be used as a unique plot identifier)
The files include: a 1) header page providing plot and photo-interpretative specs, 2) a shapefile uniquely identifying each tree and snag interpreted along with an accompanying database file, 3) a downed wood shapefile, database file, and jpg image with other downed wood information

Figure A1. *Data files provided for each interpreted HRP sample plot.*

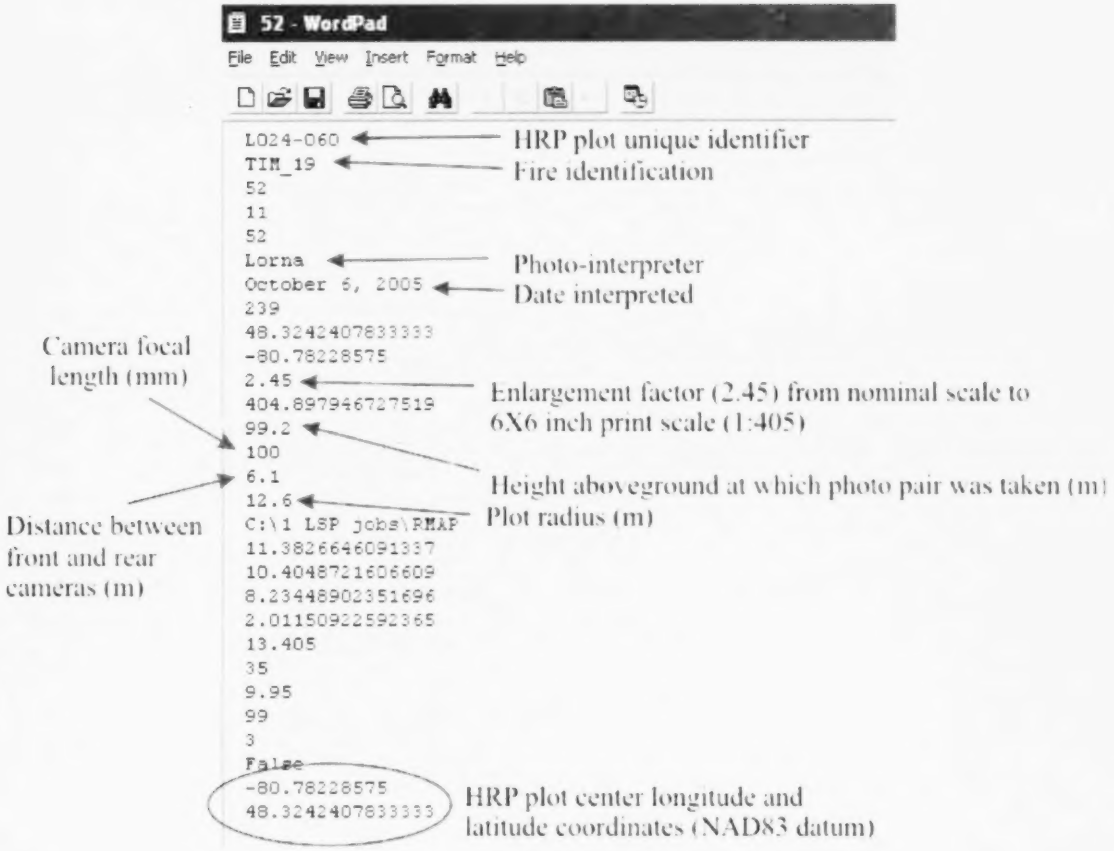


Figure A2. *Header file showing plot and photo-interpretation information for a sample plot.*

Trees are identified by a species codes, while snags are identified as either conifer or hardwood and by diameter class (e.g., C2 is a conifer snag in diameter class 2)
Longitude and latitude coordinates for each identified tree or snag
UTM coordinates for each identified tree or snag
Unique tree snag identifier for this plot
Dbh for trees as estimated by species-specific dbh-tree crown width-height-site type regressions
Fire number

Figure A3. *Database file showing tree and snag raw data.*

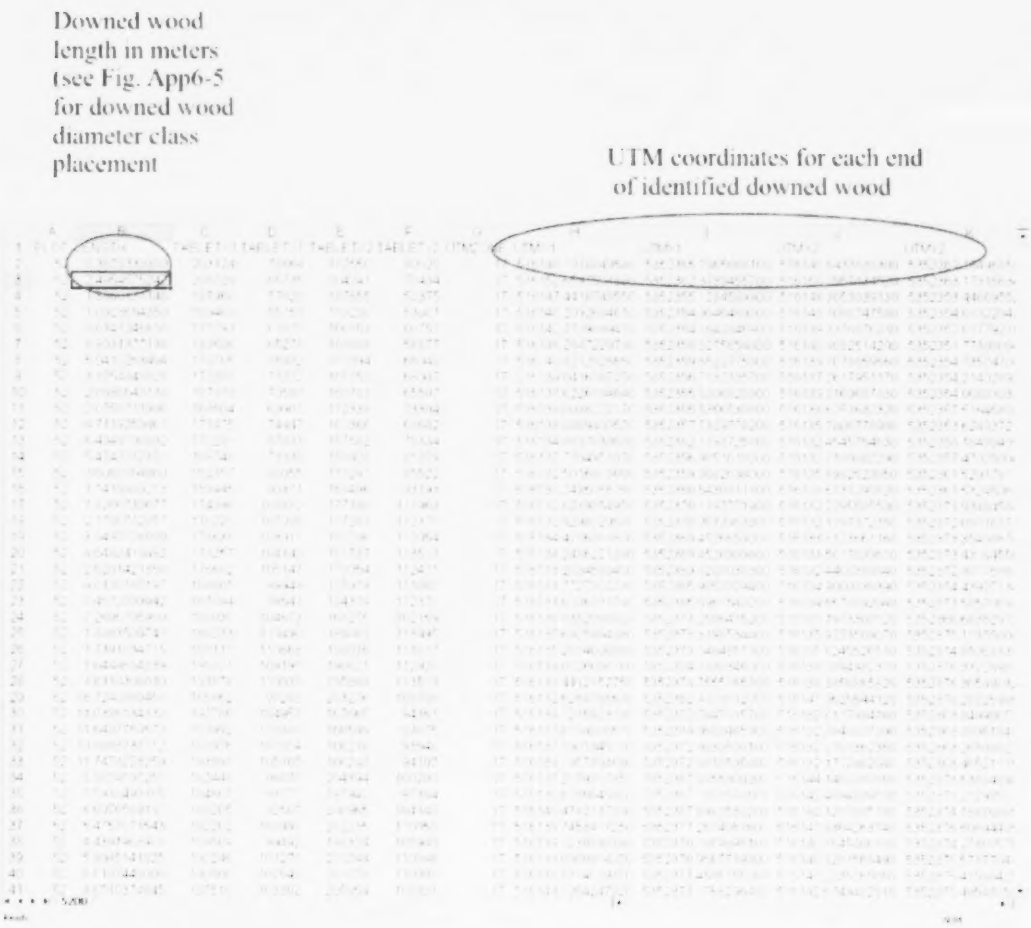


Figure A4. *Database file showing downed wood raw data (also see A6-5).*

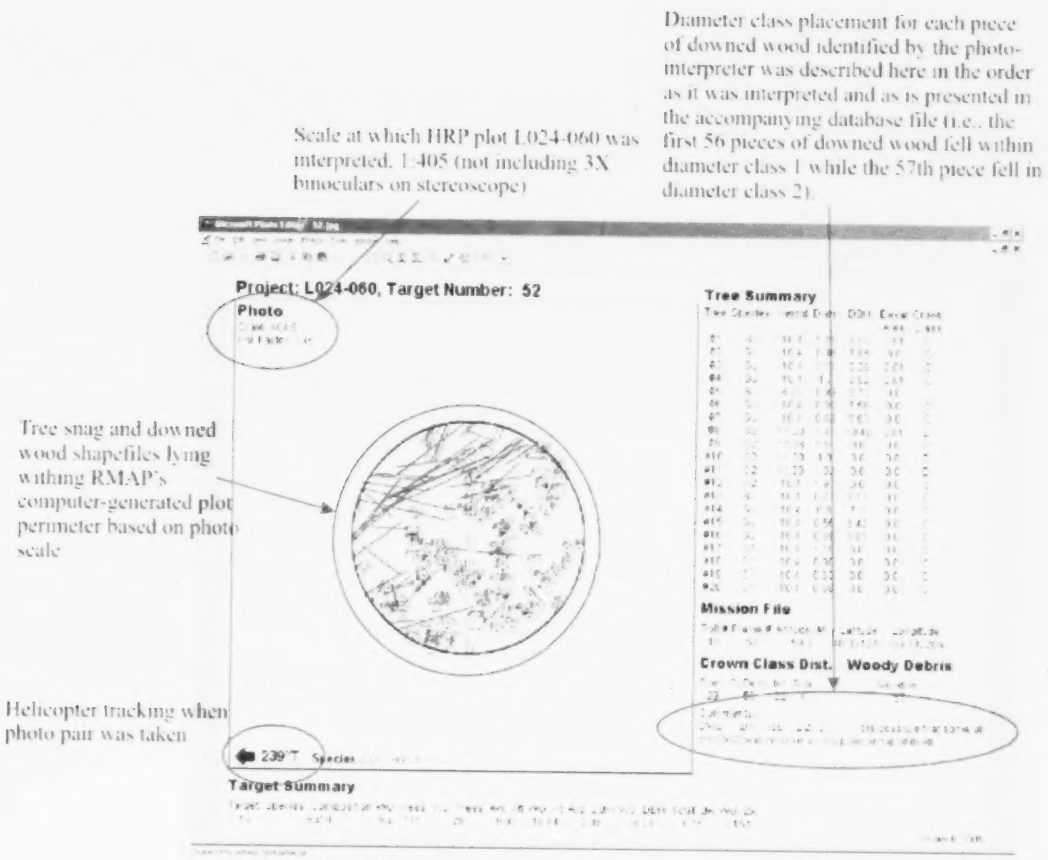

Diameter class placement for each piece of downed wood identified by the photo-interpreter was described here in the order as it was interpreted and as is presented in the accompanying database file (i.e., the first 56 pieces of downed wood fell within diameter class 1 while the 57th piece fell in diameter class 2).
Scale at which HRP plot L024-060 was interpreted, 1:405 (not including 3X binoculars on stereoscope)
Project: L024-060, Target Number: 52
Photo
Tree snag and downed wood shapefiles lying within RMAP's computer-generated plot perimeter based on photo scale
Helicopter tracking when photo pair was taken
Tree Summary
Mission File
Crown Class Dist.
Woody Debris
Target Summary

Figure A5. *Image showing downed wood diameter class placement and shapefiles generated for downed wood and trees and snags.*

APPENDIX V. Sample data sheets used for collecting field plot data

Datasheets used to collect site information (#1), forest floor fire severity (#2), tree and snag condition (#3), and downed wood measurements (#4) on field sample plots are provided below.

Datasheet #1 – Plot and site information

Plot Site Information

Fire ID: _____ **Photo Plot ID**: _____ **Field Plot ID**: ____

Date: _____ **Crew**: _____

OBM Map Sheet: _____ **Plot Size**: 500m^2 **Plot Radius**: 12.6 m

Roll / Rear Photo #: ____ ____ **Photo tracking (towards text imprint)**: _____

Plot Location (NAD83): UTM Zone: ____ Easting: _____ Northing: _____

Plot Location (NAD83): Latitude: _____ Longitude: _____

Stand composition within/surrounding plot: (e.g., Sb95 Pj5) _____

Prefire Understory % Cover Composition Within Plot: (e.g., alder 5%, Sb 2%) _____

% Slope (high point on plot edge thru plot center to low point on plot edge): _____

Aspect (downslope azimuth plot edge to edge): _____

Slope position (select 1 or more that describe the site): crest upper middle lower toe flat

Plot Access (map is not drawn to scale)

N

Local Contacts:

Datasheet #2 – Forest floor fire severity

Forest Floor Fire Severity

Fire ID: _____ Photo Plot ID: __ __ - __ __ __ Field Plot ID: ____

Date: _____ Crew: _____

		Depth (1.0cm)					Substrate (check appropriate substrate or record depth for multiple substrate layers)			
		Litter	BURNED duff/litter	BURNED moss	UNBURNED duff/litter	UNBURNED moss	mineral soil	rock	log, stump, root	other (specify)
seedbed EAST transect	12m									
	11m									
	10m									
	9m									
	8m									
	7m									
	6m									
	5m									
	4m									
	3m									
	2m									
	1m									
centre stake										
seedbed WEST transect	1m									
	2m									
	3m									
	4m									
	5m									
	6m									
	7m									
	8m									
	9m									
	10m									
	11m									
	12m									

Datasheet #3 – Tree and snag condition

Trees and Snags

Fire ID: _____ **Photo Plot ID:** __ __ - __ __ __ **Field Plot ID:** _____

Date: _____ **Crew:** _____

Interp #	Field #	Field structure (snag or tree)	Field tree crown scorch	species	Field snag fire-killed or pre-fire	Snag/Tree Height (meters)	Field tree/snag % bole remaining if BROKEN	Field diam ACTUAL	Decay status

Datasheet #4 – Downed wood measurements

Downed Wood

Fire ID: _____ Photo Plot ID: __ __ - __ __ __ Field Plot ID: _____

Date: _____ Crew: _____

Field #	Interp #	Length within plot (0.1m)	Diameter @ center (0.1 cm)	pre or post-fire fall?	Species	Orientation (degrees)	Decay 1 = Hard, 2 = partial decay, 3 = heavy decay	Bole 1 = green leaves, 2 = fine twigs, 3 = course branches or stubs, 4 = no branches	Bark % 0 = 0%, 1 = 1-24%, 2 = 25-49%, 3 = 50-74%, 4 = 75-99%, 5 = 100%	Consumption 1 = no burn, 2 = mod. light char, 3 = heavy char, mod light burn, 4 = heavy burn

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